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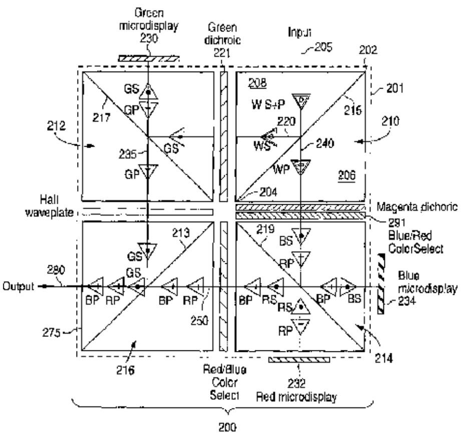
(54)【発明の名称】映像投写光管理システムの構成及び組み立てのための方法及び装置

(57)【要約】
【解決手段】光路長整合されたプリズムアセンブリ（２０１）は、異なる精度を有する偏光ビームスプリッタ光学部品（２１０、２１２、２１４、２１６）を光路長整合位置に配置し、ベースプレート又はフレームに固定することにより構成される。光学部品間の隙間はフレーム又は接着密閉材により密封する。平面光学素子（２２１、２９１）を光学素子間に挿入し、光学部品及び素子間のスペースには、部品及び素子の両方の屈折率に近い屈折率を有する光結合流体を充填する。膨張補償デバイス（５５０）をプリズムアセンブリに取り付け、光結合流体の膨張及び収縮を補償する。プリズムアセンブリはＨＤＴＶや高品位ビデオプロジェクタに用いて最適である。



【特許請求の範囲】
【請求項１】
光路長整合位置に配置された光学部品群と、
各光学部品に取り付けられ、光学部品間からの光結合流体の漏出を防止するように配置されたフレームとを備えることを特徴とするプリズムアセンブリ。
【請求項２】
各光学部品に接触して各光学部品間にある光結合物質をさらに備えることを特徴とする請求項１記載のプリズムアセンブリ。
【請求項３】
前記光結合物質は液体であることを特徴とする請求項２記載のプリズムアセンブリ。
【請求項４】
前記光結合物質は気体混合物であることを特徴とする請求項２記載のプリズムアセンブリ。
【請求項５】
前記気体混合物は空気であることを特徴とする請求項４記載のプリズムアセンブリ。
【請求項６】
前記光学部品は、光学部品の一面にある少なくとも１つの反射防止被膜を有することを特徴とする請求項５記載のプリズムアセンブリ。
【請求項７】
前記光結合物質は気体であることを特徴とする請求項２記載のプリズムアセンブリ。
【請求項８】
前記光結合物質はゲルであることを特徴とする請求項２記載のプリズムアセンブリ。
【請求項９】
前記光結合物質は紫外線硬化型接着剤であることを特徴とする請求項２記載のプリズムアセンブリ。
【請求項１０】
前記光路長整合位置は物理的に光路長整合が行われていることを特徴とする請求項１記載のプリズムアセンブリ。
【請求項１１】
前記光学部品は少なくとも１つの偏光ビームスプリッタを有することを特徴とする請求項１記載のプリズムアセンブリ。
【請求項１２】
光学部品の外表面の配置を固定するように構成されたコーナーブロック群をさらに備えることを特徴とする請求項１記載のプリズムアセンブリ。
【請求項１３】
偏光、ビームスプリット、ビーム反射、ビーム結合のうち、少なくとも１つを行うように構成された非精密寸法を有する少なくとも２つの光学部品であって、プリズムアセンブリ内の種々の光路を通って焦点に向けて方向付けられたビーム光路が整合するような位置に固定された光学部品と、
光学部品のうちの少なくとも１つに接触するように前記光路内に配置された光結合流体とを備えることを特徴とするプリズムアセンブリ。
【請求項１４】
光学部品の非精密寸法は、光学部品を取り付けても、前記光路が、プリズムアセンブリを通って方向付けられたビームに焦点を与えずに焦点の手前で再結合するような精度に整合されることを特徴とする請求項１３記載のプリズムアセンブリ。
【請求項１５】
光学部品群と、
光学部品のうちの少なくとも１つに取り付けられたベースプレートと、
光学部品のうちの少なくとも２つに取り付けられた密閉材と、
密閉された光学部品間に配置された光結合流体とを備えることを特徴とするプリズムアセ

ンブリ。
【請求項１６】
前記密閉材は、隣接する密閉された光学部品間の内部光学面を接続する接着剤であることを特徴とする請求項１５記載のプリズムアセンブリ。
【請求項１７】
隣接する密閉された光学部品のうちの少なくとも１つの間に配置された、少なくとも１つの平面光学部品群をさらに備えることを特徴とする請求項１６記載のプリズムアセンブリ。
【請求項１８】
光結合流体内に封入されたスペーサをさらに備えることを特徴とする請求項１７記載のプリズムアセンブリ。
【請求項１９】
平面光学部品のうちの少なくとも１つは、隣接する光学部品間の密閉材を分割することを特徴とする請求項１７記載のプリズムアセンブリ。
【請求項２０】
前記光学部品群は、方形状に配置された４つの偏光ビームスプリッタ（ＰＢＳ）からなり、
前記密閉材は、ＰＢＳの内部光学面を密閉して光結合流体密閉容器を形成することを特徴とする請求項１５記載のプリズムアセンブリ。
【請求項２１】
方形は正方形であることを特徴とする請求項２０記載のプリズムアセンブリ。
【請求項２２】
方形は、３つの異なる光ビームについてプリズムアセンブリを通る光路長整合された光路を有することを特徴とする請求項２０記載のプリズムアセンブリ。
【請求項２３】
３つの異なる光ビームは、赤色、緑色、青色であり、それぞれ、対応する光路の異なる位置にてスペクトルの他の部分を含むことを特徴とする請求項２２記載のプリズムアセンブリ。
【請求項２４】
光結合流体内に気泡をさらに有することを特徴とする請求項１５記載のプリズムアセンブリ。
【請求項２５】
前記気泡は、プリズムアセンブリを通る光路長外にあることを特徴とする請求項２４記載のプリズムアセンブリ。
【請求項２６】
光結合流体内に気泡をさらに有することを特徴とする請求項１５記載のプリズムアセンブリ。
【請求項２７】
前記気泡には空気が充填されることを特徴とする請求項２６記載のプリズムアセンブリ。
【請求項２８】
前記気泡には可撓性膨張／収縮材料が充填されることを特徴とする請求項２６記載のプリズムアセンブリ。
【請求項２９】
前記光学部品群は、方形状に配置された４つの偏光ビームスプリッタ（ＰＢＳ）部品からなり、各ＰＢＳが各角部にあり、各隣接ＰＢＳ間に光路整合空間があり、各ＰＢＳ間に中央充填領域が中央に配置され、
前記気泡は、プリズムアセンブリを通る光路外の中央充填領域に配置されることを特徴とする請求項２６記載のプリズムアセンブリ。
【請求項３０】
前記光学部品群は、方形状に配置された４つの偏光ビームスプリッタ（ＰＢＳ）部品から

なり、各ＰＢＳが各角部にあり、各隣接ＰＢＳ間に光路整合空間があり、各ＰＢＳ間に中央充填領域が中央に配置され、
前記プリズムアセンブリは、中央充填領域を覆って密閉するように構成されたキャップをさらに備えることを特徴とする請求項２６記載のプリズムアセンブリ。
【請求項３１】
光結合流体は、光学部品と密閉材とベースプレートとの間に維持されることを特徴とする請求項１５記載のプリズムアセンブリ。
【請求項３２】
開放端と閉塞端とを有し、開放端が光結合流体に接触しているチューブと、
チューブ内に配置された気泡とをさらに備えることを特徴とする請求項１５記載のプリズムアセンブリ。
【請求項３３】
第１の端部と第２の端部とを有し、第１の端部が光結合流体に接触し、第２の端部がプリズムアセンブリの外方に開放されている端部開放チューブと、
前記チューブ内に配置され、光結合流体の膨張及び収縮により移動するように構成された密閉可動ピストンとをさらに備えることを特徴とする請求項１５記載のプリズムアセンブリ。
【請求項３４】
ピストンの移動を制限するように構成された少なくとも１つのストッパをさらに備えることを特徴とする請求項３３記載のプリズムアセンブリ。
【請求項３５】
光結合流体に対する開口部に配置されて密閉するダイアフラムをさらに備えることを特徴とする請求項１５記載のプリズムアセンブリ。
【請求項３６】
白色光源と、
反射型マイクロディスプレイ群と、
白色光源からの白色光を光ビーム成分に分離し、各光ビーム成分を反射型マイクロディスプレイのうちの１つに向けて方向付け、反射された光ビーム成分を再合成して出力ビームを形成するように構成されたプリズムアセンブリと、
出力ビームを投写するためのレンズと、
前記プリズムアセンブリが、光路長整合された光学部品群と光学部品間に散在する結合流体とを備える場合、投写された出力ビームを表示するスクリーン画面と
を備えることを特徴とする高品位モニタ。
【請求項３７】
光ビーム成分は赤色、緑色、青色であることを特徴とする請求項３６記載の高品位モニタ。
【請求項３８】
前記高品位モニタは、高品位テレビ（ＨＤＴＶ）の一部であることを特徴とする請求項３６記載の高品位モニタ。
【請求項３９】
マイクロディスプレイを制御するための電子部品をさらに備えることを特徴とする請求項３６記載の高品位モニタ。
【請求項４０】
結合流体は、光学部品の屈折率と同等の屈折率を有する光結合流体からなることを特徴とする請求項３６記載の高品位モニタ。
【請求項４１】
ビームスプリッタを特徴とする請求項３６記載の高品位モニタ。
【請求項４２】
前記光学部品は、偏光ビームスプリッタ、偏光感度反射型ビームスプリッタ、一方向反射型ビーム結合器のうちの少なくとも１つからなることを特徴とする請求項３６記載の高品

位モニタ。
【請求項４３】
ベースプレートに光学部品群を固定し、
光学部品間の空間を密閉し、
光学部品間の空間に光結合流体を充填するステップを有することを特徴とするプリズムアセンブリの構成方法。
【請求項４４】
光結合流体は、光学部品の屈折率の２５％以内の屈折率を有する、鉱油及び他の流体のうちの少なくとも１つであることを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項４５】
光結合流体にスペーサを浮遊させることを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項４６】
平面光学部品に光結合流体を塗布し、光学部品間に平面光学素子を挿入するステップをさらに有することを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項４７】
前記固定するステップは、
光学部品を光路長整合構成に配置し、
光路長整合構成をベースプレートに取り付けるステップからなることを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項４８】
前記取り付けるステップは、光路長整合構成をベースプレートに接着することを特徴とする請求項４７記載のプリズムアセンブリの構成方法。
【請求項４９】
膨張補償デバイスをプリズムアセンブリ内に設置するステップをさらに有することを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項５０】
前記膨張補償デバイスは、可撓性物質が充填された気泡からなることを特徴とする請求項４９記載のプリズムアセンブリの構成方法。
【請求項５１】
前記膨張補償デバイスは、スライドピストンを有する端部開放チューブからなることを特徴とする請求項４９記載のプリズムアセンブリの構成方法。
【請求項５２】
前記膨張補償デバイスは、プリズムアセンブリの光結合流体内への開口部上に密閉された可撓性ダイアフラムからなることを特徴とする請求項４９記載のプリズムアセンブリの構成方法。
【請求項５３】
前記膨張補償デバイスは、光結合流体に接触する開放端と気泡を保持する閉塞端を有するチューブからなることを特徴とする請求項４９記載のプリズムアセンブリの構成方法。
【請求項５４】
前記膨張補償デバイスは、光結合流体内に配置された気泡からなることを特徴とする請求項４９記載のプリズムアセンブリの構成方法。
【請求項５５】
光学部品間に平面光学素子を挿入するステップをさらに有することを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項５６】
光学部品間に平面光学素子を挿入するステップをさらに有し、
前記充填するステップは、光結合流体内にスペーサを浮遊させる光結合流体を、光学部品間の空間に充填することを特徴とする請求項４３記載のプリズムアセンブリの構成方法。

【請求項５７】
前記光学部品は、光路長整合された方形状に配置された４つの偏光ビームスプリッタ（ＰＢＳ）からなることを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項５８】
前記密閉するステップは、光学部品のそれぞれの周囲にフレームを固定することを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項５９】
前記密閉するステップは、光学部品のそれぞれの間に接着剤を塗布することを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項６０】
前記空間を充填するステップは、注射器又は他のタブ系注入装置のいずれかを用いて、光結合流体を注入することを特徴とする請求項４３記載のプリズムアセンブリの構成方法。
【請求項６１】
前記光学部品を配置するステップは、プリズムアセンブリの外寸を設定するブロックを有するツールに、光学部品を設置することを特徴とする請求項４７記載のプリズムアセンブリの構成方法。
【請求項６２】
前記ブロックはコーナーピースであり、各コーナーピースは光学部品のうちの１つの外表面を位置決めするように構成されることを特徴とする請求項６１記載のプリズムアセンブリの構成方法。
【請求項６３】
前記ブロックのうちの少なくとも１つはエアダクトを備え、エアダクトが設けられたブロック内に設置された光学部品に真空状態を与えるとともに、エアダクトが設けられたブロックに対して光学部品を強固に保持するように構成されることを特徴とする請求項６１記載のプリズムアセンブリの構成方法。
【発明の詳細な説明】
【技術分野】
【０００１】
本発明は光管理システム（Light Management System：以下、ＬＭＳという。）に関する。特に、本発明は、ＬＭＳの改良と、反射型マイクロディスプレイ（reflective microdisplay）ベースのビデオプロジェクタへのＬＭＳの適用に関する。
【背景技術】
【０００２】
光管理システム（ＬＭＳ）は、光学機器、特に投写映像装置において用いられ、一般に光源と、集光器と、カーネル（kernel）と、投写レンズと、表示スクリーンと、関連した電子部品とを備えている。ビデオプロジェクタ１００の各部品の機能について、図１を参照して説明する。図１に示すように、光源１０５により白色光１１０が発生される。この白色光１１０は、集光器１１５により集光され、均一化され、適切な形状に成形される。フィルタ（例えばホットミラー１１６及びコールドミラー１１７）により紫外線（ＵＶ）成分及び赤外線（ＩＲ）成分が除去される。その後、白色光１１０はプリズムアセンブリ１５０に入射し、偏光されて赤色，緑色、青色の偏光ビームに３原色分離される。反射型マイクロディスプレイ１５２Ａ、１５２Ｂ、１５２Ｃのセットが設けられ、各偏光ビームに対応するように配設されている（以下、マイクロディスプレイ付きのプリズムアセンブリ１５０をカーネルという。）。各偏光ビームは、それぞれが特定の反射型マイクロディスプレイに向かうように、プリズムアセンブリ１５０内の異なる光路を通る。緑色ビームに作用する（反射する）マイクロディスプレイは、フルカラービデオ画像の緑色の情報内容を表示する。反射された緑色ビームは、フルカラービデオ画像の緑色の情報内容を含んでいる。青色及び赤色マイクロディスプレイについても同様である。マイクロディスプレイ１５２Ａ、１５２Ｂ、１５２Ｃは、画素単位で色ビームを変調して反射する。そして、プリズムアセンブリ１５０は、変調ビームを再度色合成して、フルカラービデオ画像を有す

る変調白色光ビーム１６０を生成する。得られた変調白色光ビーム１６０は、プリズムアセンブリ１５０から出射されて、投写レンズ１６５に入射する。そして、画像を有するビーム（白色光ビーム１６０は変調されてフルカラー画像を有している）がスクリーン１７０に投写される。

【０００３】

市販のプリズムアセンブリには、以下のようなものがある。

＊デジタル・リフレクション社（Digital Reflection）のスター・プリズム（Star Prism）

＊フィリップ社（Philip）のトライクロイック・プリズム（Trichroic Prism）

＊アイービーエム社（IBM）の３ＰＢＳによるＸプリズム（X Prism with 3 PBS）

＊Ｓヴィジョン／オーロラシステム社（S-Vision/Aurora System）のオフアクシス・プリズム（Off-Axis Prism）

＊デジタル・リフレクション社（Digital Reflection）のＭＧプリズム（MG Prism）

＊カラーリンク社（ColorLink）のカラークワッド・プリズム（ColorQuad Prism）

＊アナクシス社（Unaxis）のカラーコーナー・プリズム（ColorCorner Prism）

【０００４】

プリズムアセンブリ１５０においては光路長の整合が精密に行われる。すなわち、プリズムアセンブリ１５０における３つのマイクロディスプレイ１５２Ａ、１５２Ｂ、１５２Ｃのそれぞれから出射面（出力面）１５５までの光学距離は本質的に同じである。これにより、各マイクロディスプレイ１５２Ａ、１５２Ｂ、１５２Ｃは投写レンズ１６５にて同時に焦点を合わせることが可能となる。現在入手可能なプリズムアセンブリの殆どは、プリズムアセンブリの構成が、精密に形成されて互いに接着された光学部品からなる。これを達成する特定の構成技術には、種々の利点と問題点がある。

【０００５】

幾つかのプリズムアセンブリの構成においては、マイクロディスプレイとマイクロディスプレイが取り付けられたプリズムアセンブリの面との間にエアギャップを設けたものもある。エアギャップは、光路長の整合を達成するための合理的な手法であるが、問題点も多い。例えば、マイクロディスプレイの外表面とプリズムアセンブリの各面に反射防止のための（anti-reflection：ＡＲ）コーティングが必要である。３つのマイクロディスプレイは、マイクロディスプレイの６つ軸（ｘ軸、ｙ軸、ｚ軸、ロール軸、ピッチ軸、ヨー軸）の全てに対して互いに位置合せが行われる。位置合せは、一般に機械的ポジショナ（positioner）を用いて行う。一旦位置合せをしても、機器輸送中の機械的衝撃や、ビデオプロジェクタの使用中に発生する熱膨張／収縮に対して、必要な精度の位置合せを維持できるかどうかという問題が残る。また、ＡＲ表面を劣化させる虞がある埃、水分、その他の大気汚染物質に、ＡＲ表面が晒される。これら全ての要因は、ビデオプロジェクタの性能を低下させてしまう。

【０００６】

他のプリズムアセンブリの構成においては、マイクロディスプレイがプリズムアセンブリの各面に接着されている。光路長の整合は、プリズムアセンブリの寸法を「完璧なもの」（非常に高精度）にすることにより達成される。これらの「完璧な」寸法を得るために現在考えられる技術としては、以下のものがある。

【０００７】

１．許容誤差が小さい部品の製作

元になる部品を許容誤差を狭くして製作すればよい。しかし、このような部品は現在、光学部品産業界における販売業者から大量に入手できない。入手できたとしても、非常に高価である。

【０００８】

２．寸法による部品の選別

在庫の部品をそれぞれ測定し、同じ寸法の部品を揃える。そして、この揃えた部品を用いてプリズムアセンブリを組み立てる。しかし、これには、適合する部品の組を選別するた

めに部品を多く在庫する必要がある。

【０００９】

３．自動組立機械の利用

この機械は、各光学部品の寸法を測定して、組立作業中に部品の位置を能動的に調整する。このような機械は、注文設計しなければならず、非常に高価で融通が利かないと思われる。

【００１０】

３つのケースの全てにおいて、光学部品をプリズムアセンブリに組み立てる過程では、極めて厳しい許容誤差を採られなければならない。３つのケースの全てにおいて、組み立てられたプリズムアセンブリの光路長は整合していても、その外寸の範囲は広くなることがある。このため、投写レンズに対してプリズムアセンブリの位置を機械的に調整するための機構をビデオプロジェクタ内に設ける必要がある。マイクロディスプレイを接着することにより、プリズムアセンブリの組立がより難しくなるが、マイクロディスプレイの位置ずれの可能性を排除できるという利点がある。また、接着による一体化の構成により、表面の露出及び劣化の可能性を排除することができる。

【００１１】

プリズムアセンブリの各部品は、幾つかの異なる種類のプラスチック及び／又はガラス材料からなる。これらの異なる種類の材料は接着される。しかし、各材料はそれぞれ異なる熱膨張係数を有するので、問題が生じる。プリズムアセンブリとその部品は、運用中に加熱され、冷却されることは避けられないので、その結果生じる材料の膨張／収縮により応力が発生する（実際、組立工程自体がプリズムアセンブリに機械的応力を与える可能性がある）。機械的応力により光複屈折が発生する。複屈折はプリズムアセンブリを通る光ビームに偏光を生じさせ、望ましくないアーティファクトとしてスクリーン上で視覚されることがある。したがって、プリズムアセンブリ内の応力発生を最小限に抑えることが重要である。応力を最小限に抑える１つの手法は、数多くの光学的必要条件を満たすだけでなく、複屈折を誘起する応力の係数ができるだけ低いガラスを用いることである。このようなガラスの一例として、ショット社（Schott）のＳＦ－５７がある。このようなガラスの使用により状況を改善できるが、問題を解決するわけでない。

【発明の開示】

【発明が解決しようとする課題】

【００１２】

上述した説明により、マイクロディスプレイをプリズムアセンブリの各面に直接取り付けることによって、多くの利点が得られることが明らかである。しかし、光路長の整合を行ったり、直接取り付けることに適したマイクロディスプレイを用意したりするための費用等、他の様々な問題がある。さらに、ＬＭＳの製造業者は、いずれのプリズムアセンブリ構造でも大量生産においてこのような手法を実行しようとするのは困難である。本明細書に開示された発明は、プリズムアセンブリ、及び殆どのプリズムアセンブリ構成（上述した構成の全てを含む）に適用できる組立技術である。これにより、後の工程でプリズムアセンブリの各面にマイクロディスプレイを直接取り付けることができるとともに、光路長が整合したプリズムアセンブリを、安価に大量生産することができる。

【課題を解決するための手段】

【００１３】

本発明は、光管理システム（ＬＭＳ）について費用効果の高い光路長整合及び製造技術、特にプリズムアセンブリの構成とプリズムアセンブリへのマイクロディスプレイの取付という要求を満たしている。本発明は、プリズムアセンブリを構成するための新たなアプローチを記載しており、既知の構成技術の結果プリズムアセンブリ内に発生する機械的応力による望ましくない光学的効果を最小限にするものである。また、本発明は、光路長の整合が行われたプリズムアセンブリを構成する安価な配置及び方法を含むものである。この配置及び方法では、比較的安価で入手が容易な光学部品を用いる。光学的には、本方法により製作される各プリズムアセンブリは本質的に同じであるため、機械的調整を殆ど必要

とすることなく１台のビデオプロジェクタに使用できる。本発明は、広範囲のプリズムアセンブリ構成に適用可能であり、プリズムアセンブリの性能のうち望ましい機械的又は光学的特性を失うことがない。

【００１４】

一実施例において、本発明は、光路長整合が行われた位置に配置された光学部品群と、光学部品のそれぞれに接触するとともに光学部品のそれぞれの間にある光結合流体と、各光学部品に取り付けられるとともに光結合流体が光学部品間から漏出するのを防止するように配置されたフレームとを備えるプリズムアセンブリを提供する。

【００１５】

他の実施例において、本発明は、偏光、ビームスプリット、ビーム反射、ビーム結合のうちの少なくとも１つを行うように構成された不正確な寸法の少なくとも２つの光学部品であって、プリズムアセンブリにおける種々の光路を通って焦点に向けられたビームの光路長が整合されるような位置に固定された光学部品と、光学部品のうちの少なくとも２つに接触するように前記光路に配置された光結合流体とを備えるプリズムアセンブリを提供する。

【００１６】

さらに他の実施例において、本発明は、光学部品群と、光学部品のうちの少なくとも１つに取り付けられたベースプレートと、光学部品のうちの少なくとも２つに取り付けられた封止材と、封止された光学部品の間に配置された光結合流体とを備えるプリズムアセンブリを提供する。

【００１７】

また、本発明は、光学部品群をベースプレートに固定し、光学部品間の隙間を封止し、光学部品間の隙間に光結合流体を充填するステップを備えたプリズムアセンブリ構成方法を含む。他の種々の方法及び構成については、以下に説明する開示内容及び図面を詳細に検討することにより明らかになるであろう。

【００１８】

本発明及び本発明による利点は、添付図面とともに以下の詳細な説明を参照することにより、さらに理解されるものであり、より完全にその価値を認めることができるであろう。

【発明を実施するための最良の形態】

【００１９】

本発明の実施例を図面を参照して説明するが、図中、同一の部分又は対応する部分には同じ指示番号を付している。特に図２を参照し、本発明を適用したプリズムアセンブリの一構成例である光路及び構成部品を示す光管理システム（Light Management System：ＬＳＭ）カーネル２００について説明する。本発明に基づき、光路長の整合や他の特徴が得られる。カーネル２００は、プリズムアセンブリ２０１と、取り付けられたマイクロディスプレイ（「緑色」マイクロディスプレイ２３０、「赤色」マイクロディスプレイ２３２、「青色」マイクロディスプレイ２３４からなり、各色は、個々のマイクロディスプレイにより表示される画像の情報内容あるいは処理される光を識別するので、「」内に記載してある）とを備えている。カーネル２００は、映像投写装置の基本部品である。

【００２０】

プリズムアセンブリ２０１は、光学部品のセットと、膜と、単一のプリズムアセンブリユニットを作る整合要素とを備えている。白色光２０５は、第１の偏光ビームスプリッタ（ＰＢＳ）２１０に入射される。偏光ビームスプリッタ薄膜２１５は、白色光２１０を垂直に偏光して２つの偏光ビーム２２０と偏光ビーム２４０に分割する。プリズムアセンブリ２０１を通る光路には、それぞれ、各光路の色と偏光状態を示すように符号が付されている。例えば、入射白色光２０５にはＷＳ＋Ｐ（白色のＳ偏光とＰ偏光を意味する）という符号が付され、偏光ビーム２２０には最初はＷＳ（白色のＳ偏光を意味する）という符号が付されている。Ｓ偏光白色光２２０は、緑色ダイクロイックフィルタ２２１（緑色光を透過させて、偏光ビーム２２０を緑色Ｓ偏光ビーム（符号ＧＳ）にする）を透過して、第２のビームスプリッタ２１２に入射する。偏光ビームスプリッタ薄膜２１７は、Ｓ偏光緑

色光を「緑色」マイクロディスプレイ２３０に向けて反射する。

【００２１】

緑色マイクロディスプレイ２３０は、表示される画像の緑色の情報内容に従って偏光緑色光を処理する。「緑色」マイクロディスプレイ２３０は、緑色光の偏光状態を画素毎に変調する。例えば、表示される画像のうち、緑色の情報内容を含まない画素は変更されず、表示される画像のうち、強い緑色の情報内容を有する画素は偏光状態が９０°回転され、他の様々な緑色の内容レベルの画素は、緑色の情報内容の量に比例した量で偏光状態が回転される。また、この緑色マイクロディスプレイ２３０は、緑色光（変調済み）を再び偏光ビームスプリッタ薄膜２１７に反射する（光の反射や他の偏光効果は、マイクロディスプレイの偏光処理による）。

【００２２】

そして、偏光ビームスプリッタ薄膜２１７は、緑色光の一部を反射するとともに、残りの部分を透過させる。反射光と透過光の量は、反射された緑色光に対して行われた変調度に基づく。緑色マイクロディスプレイ２３０に向けて反射された光と同じ偏光状態の光は、再び反射される。逆の偏光状態の光（あるいは少なくとも偏光ビームスプリッタ薄膜２１７の偏光感度（polarization sensitivity）とは異なる光）は透過する。緑色光の量は、元の緑色光の全体量よりも少なく０よりも大きいが、変調量によって異なる（この具体例では、変調は偏光状態の回転量である）。

【００２３】

光ビーム２３５は、偏光ビームスプリッタ薄膜２１７を透過して戻ってきた変調緑色光を示す（例えば、十分に変調されて偏光ビームスプリッタ薄膜２１７を透過した緑色光である）。光ビーム２３５は、最後のビームスプリッタ２１６に入射し、偏光ビームスプリッタ薄膜２１３から反射される。赤色及び青色の各成分も同様に変調され、対応する偏光感度材料（polarization sensitive material）を透過又は反射されて、光ビーム２５０を生成する。変調緑色光ビーム２３５は、偏光ビームスプリッタ薄膜２１３から反射された後、ビーム２５０の赤色及び青色成分と合成され、表示される画像を含んだ白色光２８０として出力面２７５を介してプリズムアセンブリ２０１から出射される。

【００２４】

ＰＢＳ２１０、２１２、２１４、２１６も同様に構成される。この構成例では、各ＰＢＳは、２つの光学部品（例えば、プリズム２０８とプリズム２０６）と、偏光ビームスプリッタ薄膜（例えば２１５）とを備えている。偏光ビームスプリッタ薄膜は、例えば、Ｓ偏光を反射するとともにＰ偏光を透過させる被膜である。光学素子（例えば、位相差素子（retarder）、旋光素子（rotator）等）を用いて偏光を変化させ、所望の光ビームが偏光ビームスプリッタ薄膜により反射又は透過され、次の偏光ビームスプリッタ薄膜が、光学部品の構成や各光ビームの所望の光路に応じて所望の光ビームを透過又は反射するようにできる（図２は一具体例及び所望の光路を示す）。例えば、ＰＢＳ２１０が入射白色光ビーム２０５を２つのビームに分離すると、第２の光ビーム２４０が波長特定位相差素子（wavelength specific retarder、青色／赤色カラー選択素子２９１）を透過し、また、ＰＢＳ２１４は、光ビーム２４０を赤色マイクロディスプレイ２３２及び青色マイクロディスプレイ２３４にそれぞれに向かう成分ビームに分離することができる（位相差素子がない場合、白色光の光ビーム２４０の青色成分はＰ偏光のままとなり、ＰＢＳ２１４は、青色光を青色マイクロディスプレイ２３４に向けて反射するのではなく、赤色マイクロディスプレイ２３２に向けて透過してしまう）。

【００２５】

図２の構成は、４つの同様に構成されたＰＢＳからなるプリズムアセンブリであり、ＰＢＳを同様に構成することにより、部品点数及び特定の光学設計における部品の機能のばらつきを低減することができ、様々な機能を果たす光学部品（及び異なる構成の種々の光学部品）を用いる装置よりも有利である。したがって、これに対応する生産ラインでは、スケールメリット（economies of scale）、在庫縮小等の利点がある。なお、光学素子の様々な組合せを利用して、種々のビームを適切に反射又は透過させた後、再合成して、最終

的な光ビーム２８０を生成することもできる。さらに、種々の機能を有する光学部品を用いたプリズムアセンブリを構成することもできる。そして、上述のように、ここで説明する技術及び工程を用いて、これらの多様性の全て（異なる大きさ、異なる形状、異なる構成等）を有するプリズムアセンブリを構成することができる。

【００２６】

光学部品が組み合わされてビームスプリッタを形成する。例えば、各プリズム２０６、２０８は、組み合わされて偏光ビームスプリッタ（ＰＢＳ）２１０を形成する光学部品である。ビームスプリット光学部品を製作した後に、プリズムアセンブリを製造する。プリズムアセンブリ２０１は、４つのビームスプリット光学部品、すなわち偏光ビームスプリッタ（ＰＢＳ）２１０、２１２、２１４、２１６を備えている。各偏光ビームスプリッタ（以下、ＰＢＳと呼ぶ）２１０、２１２、２１４、２１６は、偏光ビームスプリッタ薄膜（例えば、２１５、２１７、２１９、２１３）を有している。好ましくは、偏光ビームスプリッタ薄膜は、偏光ビームスプリッタの対角面にあり、ＰＢＳの外表面により画定される角部を通って延在している。例えば、偏光ビームスプリッタ薄膜２１５は、ＰＢＳ２１０の角部２０２及び２０４を通り、プリズム２０６及び２０８の対角面に沿って延在する。また、特に光が対角面全体を通過しない場合、偏光ビームスプリッタ薄膜が対角面のうちの一部の面だけに設けられ、角部には延在しないようにＰＢＳを構成してもよい。

【００２７】

このようなＰＢＳは、光路長整合を用いて組み立てられる。ＰＢＳ２１０について説明すると、２つの光学部品（プリズム）２０６及び２０８は、正確に同じ大きさなくてもよい（したがって、ＰＢＳの外寸は、特別な寸法要件を満たす必要がない）ことがわかる。ＰＢＳに対して特別な寸法要件がないので、機械的許容誤差が「ゆるい（loose）」光学部品を用いることができる。このような光学部品（及びそれらの部品を構成するのに使用されるプリズム）は、既存の光学部品販売業者が適切な適当な原価で大量に生産することができる。

【００２８】

光学部品は「裏返して（outside in）」から組み立てられる。図３に示すように、プリズムアセンブリ２０１の４つのＰＢＳのそれぞれの２つの外表面が、組立工具３１０の精密位置合せ角部３００により正確な位置に保持される。例えば、ＰＢＳ２１０の外表面は、位置合せ角部３００Ａにより決定される固定位置に保持される。

【００２９】

組立工具３１０は、精密位置合せ角部３００が固定されるベースプレート３１５を備える。位置合せ角部３００Ａ、３００Ｂ、３００Ｃ、３００Ｄは、機械的ツーリング（tooling）を用いて製作することができる。位置合せ角部３００Ａ、３００Ｂ、３００Ｃ、３００Ｄは、各ＰＢＤ２１０、２１２、２１４、２１６の外寸を精密に固定するような許容誤差で製作されるとともに、組立工具３１０のベースプレート３１５上に配置される。各位置合せ角部３００Ａ、３００Ｂ、３００Ｃ、３００Ｄは、組立中にＰＢＳ２１０、２１２、２１４、２１６を正確な位置に固定するための機構を備えている。例えば、ＰＢＳ２１０は、真空ホルダ３３０、３３５を介して位置合せ角部３００Ａにしっかりと保持される。真空ホルダ３３０、３３５は、真空管３２５を介して真空ポンプ３３０に連結されている。一実施例においては、位置合せ角部には単一の真空ホルダが存在する。

【００３０】

位置合せ角部は、光路長整合を達成するのに必要な精密な寸法精度を与えるが、高価で許容誤差の厳密な光学部品ではなく、機械的ツーリングにより得られる。しかしながら、光路長整合だけでは満足のいくプリズムアセンブリは製作できない。光路長が整合されていても、光学部品は変化する非精密許容誤差（種々の寸法）を有しているので、ＰＢＳは精密に嵌合せず（例えば、ＰＢＳ２１０とＰＢＳ２１４の交差部や、それらの間に配設されたダイクロイックやフィルタは正確には嵌合せず）、ＰＢＳの内部光学面にエアギャップができてしまう。このエアギャップ自体により、屈折や他の光学特性の変動等、軽減又は排除しなければならない問題が発生する。

【００３１】
本発明は、ＰＢＳを液体で結合することにより、不正確に合わせられたＰＢＳの望ましくない影響を軽減する。一実施例において、プリズムアセンブリの内部光学面全てを、液体を用いて結合する。図４は、光学アセンブリの構成部品を液体結合した本発明の一実施例を示す図である。隣接するＰＢＳの間には、液体が充填されたジョイントがある。液体充填ジョイントの厚さは、プリズムアセンブリの所望の外部寸法を維持するように（例えば、プリズムアセンブリ内の整合された所望の光路長を維持するように）、個々のＰＢＳ（あるいは他のプリズムアセンブリにおいて用いられる他の光学部品）の寸法の違いよって異なる。例えば、ＰＢＳ２１２とＰＢＳ２１６の間のジョイントである液体充填ジョイントＪ１は、ＰＢＳ間の液体からなり、ジョイント全体は、スペースｔ１、ｔ２、ｔ３内の液体結合流体４００と、ＰＢＳ間に配置されたダイクロイックや他の光学素子（例えば、ＰＢＳ間に配置された光学素子４１０及び４２０）とからなる。他の光学素子は、例えば、ダイクロイック又は他のフィルタの組合せであってもよい。液体結合流体内に収容するにより、部品内に応力が蓄積されるのを防止する。

【００３２】
一実施例において、プリズムアセンブリの外部表面に接着されたフレームを用いて、液体を封入するとともに部品を正確な位置に保持する。図５は、本発明の一実施例によるＬＭＳプリズムアセンブリの部品を保持するフレーム５００の上面図及び側面図である。フレーム５００は、１又は幾つかのピースで構成することができ（フレーム材料について光学的な必要条件は何もない）、ＰＢＳ間の各ジョイント上に配置される。この実施例では、フレーム５００は、２つの面部品５００Ａ、５００Ｃと、４つのエッジ部品５００Ｂからなる。各面部品５００Ａ、５００Ｃは、プラス（＋）形状のガラス、プラスチック、アクリル、その他の材料からなり、プラス形状の各肢部がジョイントを覆い、プラス形状の中央部が４つのジョイント全ての連結部を覆う。エッジ部品５００Ｂは、各ジョイントの端部を覆う。上面部品５００Ａは、充填孔５１０を有しており、必要に応じて流体を注入及び／又は追加することができる。キャップ（図示せず）を用いて充填孔に蓋をし、流体がこぼれるのを防止する。気泡５５０を設けて、液体の膨張／収縮を補償し、光学部品への応力の蓄積を防止する。フレーム５００は、プラス形状として説明しているが、各ジョイントを十分に覆うものであれば、完全な長方形又はその他の形状であってもよい。フレームに付す糊（glue）又は他の接着剤は、フレームとＰＢＳとの間に封止材を形成し、結合流体を完全に封入する。また、この糊又は他の接着剤は、フレームに対してＰＢＳの位置を固定し、ＰＢＳが互いに移動しないようにする（ＬＭＳのモノリシック特性を維持する）。

【００３３】
フレームとＰＢＳとの間に接着剤を用いた整合光路長の固定は、プリズムアセンブリ部品の整合光路長位置を決定してから（例えば、角部ピースや他の位置決め機構を有するツールを用いて、正しい光路長を確保してから）、それらの整合光路長位置にて部品（例えばＰＢＳ）をフレームの１つ以上の部分に接着することにより行われる。そして、新たな光学素子（例えば光学素子４１０、４２０）をジョイントに配置し、ジョイントに少なくとも部分的に光結合流体（液体結合流体）を充填し、上フレームピースでジョイントに蓋をし、結合流体をいっぱいに入れ（気泡又は他の膨張エアスペースを除く）、充填孔に蓋をする。

【００３４】
本発明には、プリズムアセンブリに結合液体を充填する種々の方法及び装置が含まれる。例えば、図７は本発明の一実施例による結合流体充填装置及び方法を示す図である。結合流体が充填された注射器を用いて、中央充填孔７００に結合液体を注入する。中央充填孔７００はプリズムアセンブリの中央領域であり、一般的にその内部には光学部品は存在しない。しかしながら、１つ以上の光学部品が少なくとも中央充填孔の途中まで配置されている可能性もある。一実施例において、プリズムアセンブリに結合流体を少なくとも部分的に満たした後、プリズムアセンブリにフレームの上部を取り付ける。フレームの上部が

取り付けられていないときには、結合流体を中央充填孔以外の領域に注入することができるが、中央充填孔に注入することが好ましい。また、中央充填孔の底部にて結合流体を注入することが好ましい。垂直及び水平の両方向における光学素子とＰＢＳとの毛管現象が、充填処理を促進する。他の実施例では、配置されたフレームの上部にて同じ処理が行われる。その場合、充填孔５１０（キャップは外した状態）を介して注射器を中央充填孔７００の底部に挿入し、プリズムアセンブリに結合流体を充填する。チューブ、ポンプ等の他の装置や他の注入機構を用いて、中央充填孔に流体を注入してもよい。

【００３５】

プリズムアセンブリ内の部品が直接接触する場合（例えば、光学素子４１０が光学素子４２０又はＰＳＢ２１２のいずれかに直接接触する場合）、結果として、プリズムアセンブリにより投写される画像中に目視可能なアーティファクトとして現れてしまう。この問題は、光学アセンブリの部品及び／又は素子間に液体からなる薄膜を確実に存在させることにより、解決される。部品間に液体の薄膜が確実に存在するようにするためには、種々の方法及び／又は機構を用いることができる。例えば、結合流体の充填中に光学素子を物理的に分離し、光学素子とＰＢＳとを分離するようにフレームの各部にスペーサを取り付ければよい。一実施例において、光学面間にスペーサを用いる。図６は、本発明の一実施例によるＬＭＳプリズムアセンブリのスペーサ（スペーサボール６００）と流体結合を示す図である。スペーサは、数千分の１インチ程度の直径を有するガラスロッド又はボールとすることができる。液体結合流体の屈折率は、スペーサの屈折率に一致するように選択し、したがって、スペーサは見えなくなる。

【００３６】

本発明には、スペーサを適用する様々な方法及び装置が含まれる。一群の実施例において、スペーサをＰＢＳ及び／又は光学素子の光学面に直接塗布する。一実施例では、スペーサを光学面に吹き付ける。光学面へのスペーサの吹付けは、液晶表示装置の製造技術や機械類を用いて行えばよい。湿式又は乾式スペーサ塗布のいずれを用いてもよい。他の実施例では、少なくとも製造中に、スペーサを液体結合流体中に浮遊させる。プリズムアセンブリの製造後、浮遊したスペーサは、光学面間に滞留及び／又は視界外であるプリズムアセンブリの底部に沈殿する。

【００３７】

液体結合流体は、流体内で間隔をおいたＰＳＢや光学素子の屈折率と一致する（あるいは）略一致する）屈折率を有するように選択された光結合流体である。屈折率は、波長によって変化し、プリズムアセンブリにおける部品や素子毎に異なる。プラスチック素子の場合、一般的な値は１．５２であり、ガラス部品の場合は１．７１である。光結合流体は、一般に１．５０～１．８５の範囲の屈折率を有することが好ましい。屈折率１．６の光結合流体は、本発明者等が実施した実験では十分に機能した。同様に、スペーサを用いた実施例では、光結合流体は、ＰＢＳ、光学素子、スペーサのそれぞれの屈折率に可能な限り近い屈折率を有するように選択される。屈折率の一致は、光学部品と素子間の屈折率の差を分割することにより行うことができる。他の方法としては、インピーダンス整合的な演算（例えば、各光学部品／素子の屈折率の二乗和の平方根をとる演算）を行うことである。なお、本発明者等は、光学部品及び素子の屈折率について、高い屈折率から低い屈折率までのいずれの屈折率を選択しても、本明細書で説明するゲル、硬化エポキシ、空気充填の各実施例等、光路長整合が行われたプリズムアセンブリの他のいずれの実施例よりも良好に一致させることができることを見出した。結合流体について選択した屈折率は、プリズムアセンブリでより頻繁に行われる部品界面の整合に関して有利になるようにすることができる。一実施例において、結合流体の屈折率はスペーサの屈折率と一致する。

【００３８】

結合流体に関して重要な特性は、毒性、可燃性、黄変傾向、化学特性、原価である。毒性と可燃性は安全性の問題であり、製品は非毒性、不燃性であることが好ましい。また、光結合流体が実用的であるには、特に強力な光と熱の条件下でも耐黄変性がなければならない。光結合流体は、プリズムアセンブリにおける他の光学素子、部品、部分と反応しない

化学特性を有していなければならない。そして、商業的に実用的であるには、光結合流体は比較的安価で入手が容易でなければならない。一実施例において、光結合流体は、例えば鉱油である。多くの異なる種類や特性の光結合流体が市販されている（例えば、カーギル社（Cargille Corp）は、多くの異なる種類の、屈折率が一致した流体を製造している）。

【００３９】

一実施例において、光結合流体は紫外線硬化型接着剤であり、硬化すると流体なしで光学素子／部品を結合し、頑強なプリズムアセンブリを形成する。しかしながら、液体充填の実施例では、商業的に実用的な紫外線硬化型接着剤よりも良好な屈折率の一致が得られるので、液体充填の実施例が好ましい。他の実施例では、プリズムアセンブリの種々の部品／素子間に光結合ゲルを挿入することにより光結合を行う。ＮＹＥ社（NYE Corporation）は、このようなゲル（一致するゲル）を一種製造している。さらに他の実施例では、結合材料が空気である。あるいは、光学部品と光学素子間にカプラとして他の気体を用いる。空気充填の実施例では、反射を排除又は低減するために、反射防止被膜を光学素子及び部品の表面に設ける。

【００４０】

なお、ここで説明する種々の組立技術は、本明細書で説明するプリズムアセンブリ構成のいずれにも適用することができる。

【００４１】

上述の構成及び製造方法により、幾つかの利点が得られる。これらを以下に示す。

【００４２】

幾つかのプリズムアセンブリ構成には、偏光回転素子（旋光素子（rotator））（例えば、偏光ビームスプリッタ薄膜２１７を透過した回転ビーム２３５は、偏光ビームスプリッタ薄膜２１３により反射される）が含まれる。旋光素子は、一般に、ポリカーボネートプラスチックの層を互い接着して構成される。従来の装置では、接着剤は、旋光素子のポリカーボネートプラスチックをプリズムアセンブリのガラスに接着できなければならない。この問題の一般的な解決法は、販売業者から偏光旋光素子を「挟み込み（sandwich）」状態で購入することである。「挟み込み」状態では、旋光素子が２枚のカバーガラス間に接着されている。カバーガラスにより、プリズムアセンブリ製造者が旋光素子をプリズムアセンブリ内に接着するのが容易になる（例えば、隣接するカバーガラスの表面の間に接着する）。しかしながら、ポリカーボネート製の旋光素子自体と比較して、挟み込みのものは、供給が限られており高価である。これに対し、本発明では、液体結合方法により、安価で入手が容易なポリカーボネート部品を直接使用することができる。液体結合ではポリカーボネートを接着剤で接着しないので、このような問題は生じない。

【００４３】

新たな製造方法を用いて得られたプリズムアセンブリの精密な外寸により、マイクロディスプレイをプリズムアセンブリに直接取り付けることができるだけでなく、完成したカーネル（マイクロディスプレイが取り付けられたプリズムアセンブリ）を、それが使用される装置（例えば、光エンジン）に取り付けるための精密（又は固定）取付ポイントを使用することができる。精密又は固定取付ポイントを使用することで、カーネルを光エンジンに取り付ける際に、物理的調整機構や手順の必要性が低減又は排除される。

【００４４】

従来のプリズムアセンブリは、一般に一連の糊硬化工程を用いる。プリズムアセンブリの大きさや複雑性が増すにつれて、ガラスによる光の吸収及び／又は部品の光学特性により接着剤の硬化が徐々に困難になる。本発明のような液体結合により、この問題がなくなり、プリズムの組立に必要な時間を大幅に短縮することができる。

【００４５】

本発明には、光学素子（例えば、光学素子４１０、４２０）を正確な位置に保持するための装置及び方法が含まれる。光学素子は、一般に長方形で平面状（薄い幅）なので、一般に平面部品（flat component）とも呼ばれている。なお、本発明は、種々の形状と幅の光

学部品を用いて実施することができる。

【００４６】

製造時、出荷時、保管時及び／又は実際の使用中等、いずれの場合においても問題となるのは、結合流体内で光学素子が移動する可能性があることである。中央充填孔７００側への移動により、移動した部品（あるいは移動した部品の部分）が光路から外れたままになってしまう可能性がある。本発明では、中央充填孔７００にスペーサデバイスを配置して、平面部品を安定した通常位置に保持する。図８は、本発明の一実施例による、光学部品を保持するのに用いられるスペーサデバイス８００の一例を示す図である。図示する実施例において、スペーサデバイス８００は、シリンダ形状となるようにきつく巻かれたポリカーボネートシートである。スペーサデバイス８００を中央充填孔７００に挿入する。正確な位置に配置されると、ロールシリンダは「ほどかれて」部品を押圧することにより、部品を中央孔の外に保持する。

【００４７】

上述のように、種々の部品の膨張を補償するためにプリズムアセンブリ内に気泡を残してもよい。部品の膨張に関する問題は、各部品が異なる率で膨張することである。光結合流体が膨張すると、プリズムアセンブリの光学部品も膨張する。しかしながら、液体と光学部品の膨張は異なる率である（膨張差（differential expansion））。多くの場合、光結合流体が光学部品よりも高い率で膨張する。気泡がない場合、膨張する流体により、ある量の応力が光学部品に対してかかる。気泡がない場合、この応力により、液体結合流体が膨張すると、プリズムアセンブリの光学部品を通過する種々の光ビームに影響する、応力による望ましくない量の複屈折が生じる可能性がある。

【００４８】

再び図５を参照し、気泡５５０について説明する。充填孔５１０に蓋がされると、気泡５５０はプリズムアセンブリ内に永久に保持される。図５において、プリズムアセンブリの外側の「フレーム」要素（５００Ａ、５００Ｂ、５００Ｃ）は、液体を封入するとともにプリズムアセンブリ部品の空間を強固に保持するのに役立つ。

【００４９】

図５の例示的な実施例では、フレーム５００により包囲されたプリズムアセンブリ内の容積は、プリズムアセンブリ部品（例えばＰＢＳ等）のガラス、光学素子、光結合液体で占められる。プリズムアセンブリの温度が上昇すると（動作中には温度上昇する）、全部品の線形及び体積寸法が大きくなる。しかしながら、少なくとも光結合液体の熱体積膨張係数がガラスや他の材料の熱体積膨張係数よりもかなり高いことから、温度が上昇すると、液体の体積が、ガラスの「容器」（液体の境界となる光学部品やフレーム）の体積よりも速く膨張する。望ましくない光学的影響に加えて、この膨張差により生じる過度の応力が、接着した部品を分離させてしまう可能性がある。気泡５５０は、膨張差の影響を調節するとともに応力の蓄積を防止する一手法である。

【００５０】

図９は、本発明の一実施例によるダイアフラムを備えたプリズムアセンブリを示す図である。ダイアフラム９００は、膨張する流体を調節することにより応力を緩和するのに十分な強度と可撓性を有するゴム、プラスチック、その他の可撓性材料により構成される。ダイアフラム９００は、液体の体積が増減するにつれて撓む。好ましくは、ダイアフラム９００は円形で、接着剤を用いて充填孔５１０上に取り付けられる。なお、他の形状や取付機構を用いてもよい（例えば、充填孔周囲のフレームに留めたリングの下に嵌め込んだ可撓性材料）。

【００５１】

図１０は、本発明の一実施例による気泡１０００を備えたプリズムアセンブリを示す図である。一実施例において、フレーム５００は蓋をされ（例えば、キャップ１０１０）、光学アセンブリ内に気泡１０００が挿入される。気泡１００は、液体の体積が増減するにつれて膨張及び収縮を行う。

【００５２】

気泡１０００は、充填路（中央充填孔７００）に挿入される。気泡１０００の体積は、結合流体の体積変化を調節するように増減することができる。他の実施例において、気泡は、適切な圧縮可能材料（例えば、気体、液体、固体、又はこれらの組合せ）であってもよい。また、気泡１０００は、フレームに接着されていない部品（例えば、偏光ビームスプリットキューブ間に配置された「平面」部品（例えば、光学素子４１０、４２０））を正確な位置に保持するのにも役立つ。「平面」部品を適所に保持するのに役立つように構成した場合、ポリカーボネートロール８００等のスペーサは不要である。

【００５３】

図１１は、本発明の一実施例による密閉チューブ１１００の実施例を示す図である。密閉チューブ１１００は、充填孔５１０に取り付けられる。密閉チューブ１１００の一部には気泡１１０５が封入されている。気泡１１０５は、プリズムアセンブリ内の液体の膨張又は収縮を調節するように拡大又は縮小する。この手法では、上述の気泡のみの手法と同様に、光エンジンにおけるプリズムアセンブリの方向が分かっていることが重要である。それは、気泡１１００がプリズムアセンブリ内の高い位置に移動するからである。したがって、密閉チューブ１１００の端部が高い位置になるように装置を設計する必要がある。密閉チューブは、気泡を適切な位置に向けるように肘部又は他の構造を有して構成されてもよい。したがって、気泡のみの手法の場合、プリズムアセンブリの高い位置（プリズムアセンブリにおける流体の高い位置）は、プリズムアセンブリの光路内の位置とはならないことが重要である。

【００５４】

図１２は、本発明の一実施例による外気ピストン１２００を示す図である。端部開放チューブ１２０５は、充填孔５１０に取り付けられる。スライドピストン１２００が端部開放チューブ１２０５内部にしっかりと嵌合する。光結合液体が温度上昇によって膨張すると、ピストン１２００が端部開放チューブ１２０５内で外方にスライドする。光結合液体が温度低下により収縮すると、表面張力（及び／又はプリズムアセンブリ内外の圧力の差）により、ピストン１２００が端部開放チューブ１２０５内で内方にスライドする。一実施例において、端部開放チューブ１２０５は予測される光結合流体の最大膨張よりも長い。他の実施例では、端部開放チューブ１２０５内にストッパ１２１０を配置して、ピストン１２００がチューブ１２０５の開放端に達するのを防止する。また、他の実施例において、ストッパ１２１０は、緊急停止回路に接続された電極であり、ピストン１２００は外表面に導電性材料を有している。ピストン１２００がストッパ１２１０に接触すると、少なくともプリズムアセンブリが十分に冷却されて、ピストン１２００がストッパ１２１０から離れるまで、プリズムアセンブリが搭載光エンジンが停止される。ここで説明した実施例全てについて、端部開放チューブを１以上の他の実施例（例えば気泡）と組み合わせて、光結合流体の膨張及び収縮を補償する応力緩和を行ってもよい。

【００５５】

上述の各実施例は、プリズムアセンブリを密閉するとともに光結合流体を封入する（そして、上述の応力緩和手段のために必要な取付具を備えた）外部フレーム（例えば、プリズムアセンブリの光学部品の外部であるフレーム５００）を備えている。また、フレームはプリズムアセンブリに構造的強度を与える。なお、本発明者等は、光結合流体を密閉するための小型の構造を実現した。小型は構造により、種々のＬＣｏＳベースの映像投写装置等、種々の光学的用途にプリズムアセンブリを用いることができる。

【００５６】

さらに、流体結合型プリズムアセンブリを新たな設計及び／又は既存の光エンジン装置に取り付けることができる。新たな設計の場合、液体結合型プリズムアセンブリの取付は、液体結合型プリズムアセンブリの１倍以上の大きさの取付台を投写装置内に設けることによって行うことができる。しかしながら、旧型の装置を改造した場合（以前に販売された投写装置への液体充填型プリズムアセンブリの取付、及び／又は、旧型の設計で新品の投写装置への液体結合型プリズムアセンブリの取付の場合）、液体結合型プリズムアセンブリを物理的に容易に収容することができない。すなわち、流体結合型プリズムアセンブリ

の物理的大きさや形状により、このプリズムアセンブリを、既存の光エンジン内に従来のプリズムアセンブリ用に設けられた位置に直接取り付けることができないことがある。流体結合型プリズムアセンブリを収容するのに必要な光エンジンの変更は難しく高価であり、極端な場合は不可能である。したがって、密閉されて構造的強度を有し、同等の従来のプリズムアセンブリと同様の外寸を有する流体結合型プリズムアセンブリを提供することにより、いずれの光エンジン設計においても、そのプリズムアセンブリを従来のプリズムアセンブリに代えてドロップイン（drop in）として使用することができる。本明細書に開示した発明は、そのような手段である。

【００５７】

こうした理由により、本発明者等は、液体結合型プリズムアセンブリを密閉して構造的整合性を与える内部密閉型プリズムアセンブリも開発した。

【００５８】

図１３は、本発明の一実施例による内部密閉型プリズムアセンブリ１３００を示す図である。内部密閉型プリズムアセンブリ１３００は、ベースプレート１３１０と、プリズムアセンブリの光学部品間に少なくとも１つの内部密閉材１３２０とを有している。この実施例を先の各構成と比較すると、ベースプレート１３１０を除いて、外部フレームの多くの機構がない（ベースプレートは従来及び流体結合型のプリズムアセンブリ構成に共通の機構である）。ベースプレート１３１０は、ＰＢＳ１３０１〜１３０４を取り付けるための堅固で安定した面を与える。図１３に示すように、内部密閉材は、光学素子４１０と光学素子４２０との間、光学素子４１０とＰＢＳ１３０２との間、光学素子４２０とＰＢＳ１３０３との間に充填される。内部密閉材は光学素子／ＰＢＳの上部から下方に短く延在し（例えば、１ｍｍ）、プリズムアセンブリ内に設置された光結合流体を維持する密閉材を形成する。一実施例において、内部密閉材は、光学素子の露出面を覆うように光学素子４１０、４２０の上部を覆うが、好ましくはＰＢＳの外表面を越えるものではない。深さについては、密閉材は光学素子／ＰＢＳ間において所定の密閉深さ（例えば、１ｍｍ）まで浸透する。

【００５９】

図１４は、本発明の一実施例による内部密閉型プリズムアセンブリ１４００の内部密閉材を拡大した図である（部分図）。図１４において、２つのＰＢＳ４１０１、１４０２は間に内部密閉材１４１０を有している。内部密閉材１４１０は、ＰＢＳ素子間の「画枠（picture frame）」として説明することができる。接着剤はプリズムアセンブリの外表面を越えるものではない。好ましくは、内部密閉材１４１０は、プリズムアセンブリを密閉して光結合流体の漏出を防ぐだけでなく、全体の構造に剛性を加えるような接着剤である。この接着剤は、例えば、１又は２部エポキシ、又は、紫外線硬化型接着剤であればよく、いずれも硬化して密閉を行う。

【００６０】

また、接着密閉材はシリコーン系接着剤等の柔軟性のある接着剤であってもよい。なお、非硬化密閉材を用いる場合、プリズムアセンブリの撓みが問題とことがある。フレームの底板により十分な剛性が得られ、用途によっては、柔軟性接着剤が使用可能であるが、ベースプレートに加えて上部プレート（プリズムアセンブリのベースプレートとは反対側）によりさらなる剛性が得られ、略全ての用途において柔軟性接着剤が完全に使用可能となる。

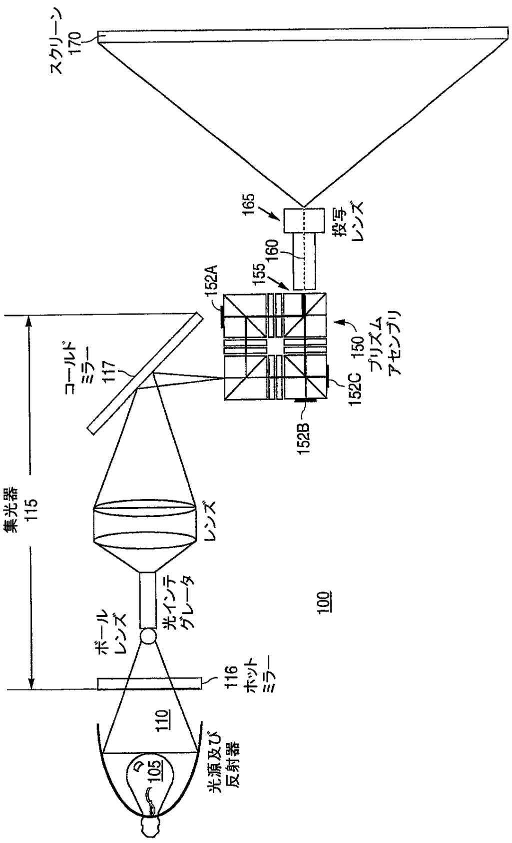
【００６１】

図１４は、スペーサ１４２０により分離された光学素子（「平面」光学部品１４３０）も示している。この光学素子は、接着密閉材の底高よりも短い。この光学素子は一例であり、実際は、さらなるスペーサを介してＰＢＳや素子同士で分離された、幾つかの光学素子であってもよい。「平面」光学部品１４１０は、ＰＢＳ間に封入され、光結合液体中に浮遊するダイクロイック、反射型偏光器、波長特定位相差素子等である。平面部品は、先に説明したようにスペーサ素子を用いることによりガラス面から間隔をおいている。接着剤１４１０の浸透（所定の密閉深さ）は光路外の領域に制限されている。ベースプレート１

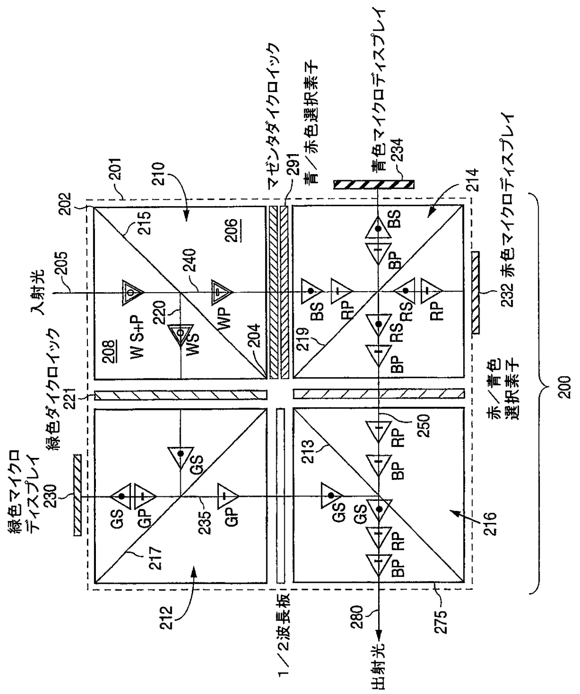
３１０により、プリズムアセンブリに必要な剛性が得られる。
【００６２】
上述のように、開示した液体結合型プリズムアセンブリ技術及び構成の主な利点としては、比較的安価で低許容誤差のガラス部品を使用することが可能であるとともに、「完全な」外寸のプリズムアセンブリを製作することが可能であり、製作の際にマイクロディスプレイをプリズム集合に直接取り付けることができる。また、後者により幾つかの利点が得られるが、まず、得られるモノリシックアセンブリが種々の条件下でも位置合せ状態を維持できることがあげられる。
【００６３】
これらの利点が得られる他の手段は、先に説明した「裏返しの状態から組み立てる」手順を用いることであるが、プリズムアセンブリに光結合液体を充填するのではなく、アセンブリを空のまま維持するので、空気を充填することになる。しかしながら、このアプローチでは、露出している表面全てに反射防止膜（ＡＲ被膜）を塗布して反射を抑制する必要がある。この構成では拡張ポートは必要ない。用途によっては、フレームのサイドレール（例えば、５００Ｂ）や上部（５００Ｃ）も省略することが可能である。
【００６４】
さらに他の例では、硬化するエポキシがプリズムアセンブリに充填される。好ましくは、硬化エポキシは、用いるＰＢＳや光学素子の屈折率に近い屈折率を有する。さらに他の実施例では、ゲル物質を用いて隣接するＰＢＳ間のジョイントを満たしてもよい。ここでも好ましくは、ゲルは、プリズムアセンブリの他の部分の屈折率に近い屈折率を有する。用いることができるゲルの一例は、ＮＹＥ社（NYE Corporation）が製造している。
【００６５】
図面に示した本発明の好ましい実施例の説明では、説明を明確にするために特定の用語を用いている。しかしながら、本発明はそのように選択された特定の用語に限定されるものではなく、各要素は同様に動作する全て技術的同等物を含むものとする。例えば、ロール状のポリカーボネートからなるスペーサデバイスを説明する際に、幾何学形状（方形、三角形、五角形、六角形等）、他の形状のポリカーボネート又は他の材料のロール、同等の機能又は能力を有する他のデバイス等、本明細書中の記載の有無にかかわらず、他の同等のデバイスはいずれも代替物として利用できる。さらに発明者等は、現在知られていない新たに開発された技術を上述の各部に代えて利用してもよく、本発明の主旨を逸脱しないことを理解している。
【００６６】
本発明は主として、個々の画素の偏光状態を回転させることにより動作するマイクロディスプレイを用いるＬＭＳとともに説明されている。しかしながら、本明細書の記載に基づき、本発明は、他の種類のマイクロディスプレイ（例えば、散乱、吸収、回折系マイクロディスプレイ）を備えた装置や、マイクロディスプレイを備えずに構成された光学装置においても実施してもよいことがわかる。
【００６７】
もちろん、上述の教示に鑑みて、本発明について多数の変形や変更が可能である。したがって、添付の特許請求の範囲の主旨を逸脱しない限り、具体的に説明したものとは異なるように本発明を実施してもよいことがわかる。
【図面の簡単な説明】
【００６８】
【図１】光管理システム（ＬＭＳ）ビデオプロジェクタの図である。
【図２】本発明を適用したプリズムアセンブリの一構成例の光路及び部品を示す、簡素化したカーネルの一例の図である。
【図３】本発明の一実施例によるＬＭＳプリズムアセンブリの構成技術を示す図である。
【図４】本発明の一実施例によるＬＭＳプリズムアセンブリにおける部品の液体結合の図である。
【図５】本発明の一実施例によるＬＭＳプリズムアセンブリの部品を保持するフレームの

上面図及び側面図である。
【図６】本発明の一実施例によるＬＭＳプリズムアセンブリの部品のスペーサ及び液体結合の図である。
【図７】本発明の一実施例による結合流体充填方法を示す図である。
【図８】本発明の一実施例によるプリズムアセンブリ部品を保持するのに用いられる機構の一例の図である。
【図９】本発明の一実施例によるダイアフラム９００を備えたプリズムアセンブリの図である。
【図１０】本発明の一実施例による気泡を備えたプリズムアセンブリの一実施例の図である。
【図１１】本発明の一実施例による密閉チューブアセンブリの一実施例の図である。
【図１２】本発明の一実施例による外気ピストン構成の図である。
【図１３】本発明の一実施例による内部密閉型プリズムアセンブリの図である。
【図１４】本発明の一実施例による内部密閉型プリズムアセンブリの内部密閉材を拡大した図である。

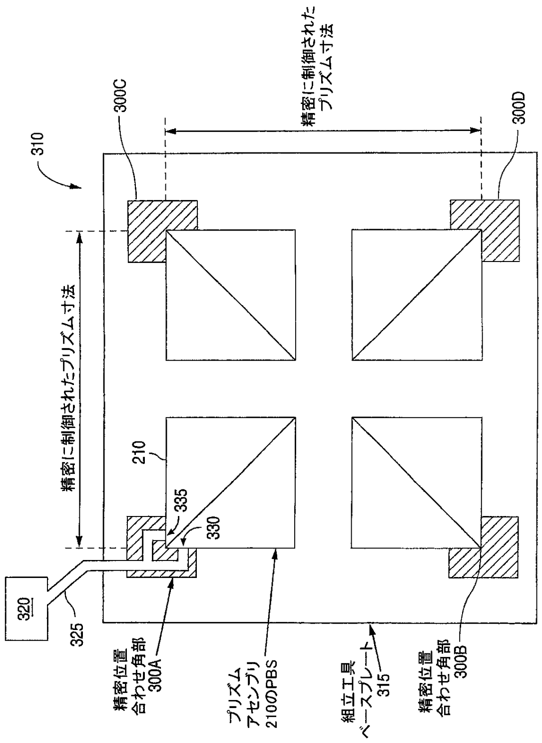
【図１】



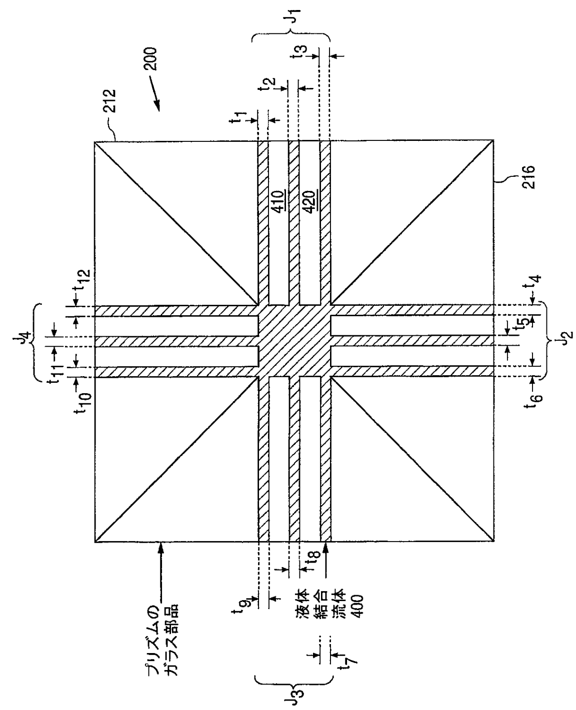
【図２】



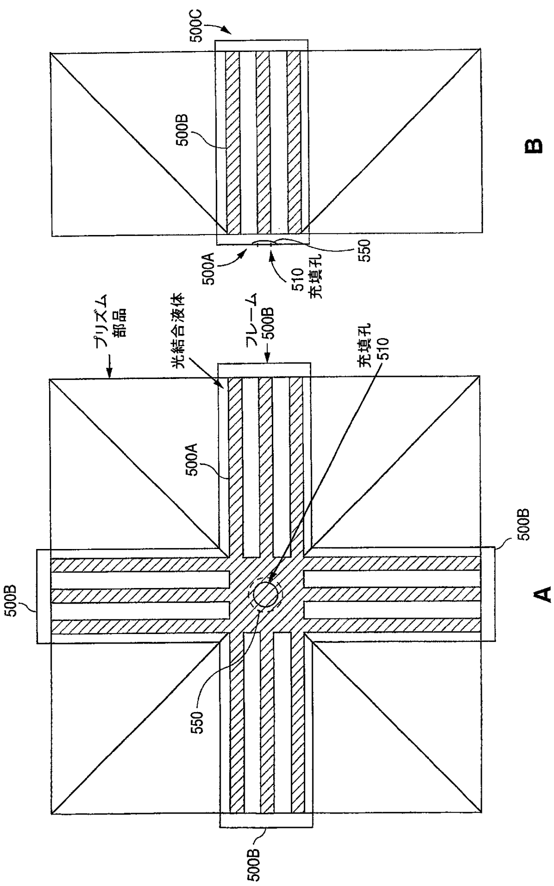
【図３】


310
300C
300D
精密に制御されたプリズム寸法
精密に制御されたプリズム寸法
210
335
330
320
325
精密位置合わせ角部 300A
プリズムアセンブリ 210のPBS
組立工具ベースプレート 315
精密位置合わせ角部 300B

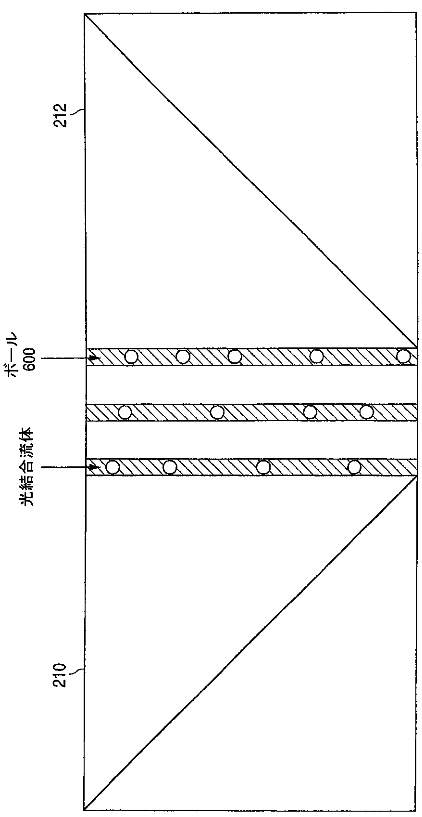
【図４】


200
212
216
410
420
プリズムのガラス部品
液体結合流体 400

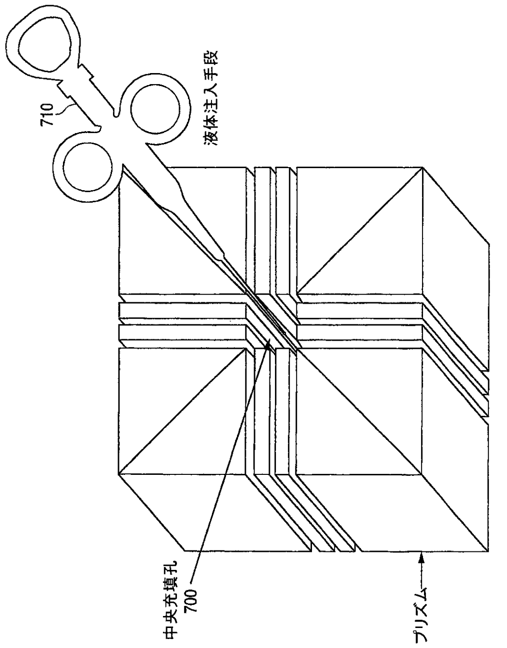
【図５】


500C
500B
500A
510 充填孔
550
B
プリズム部品
光結合液体
フレーム 500B
充填孔 510
500A
500B
500B
550
500B
A

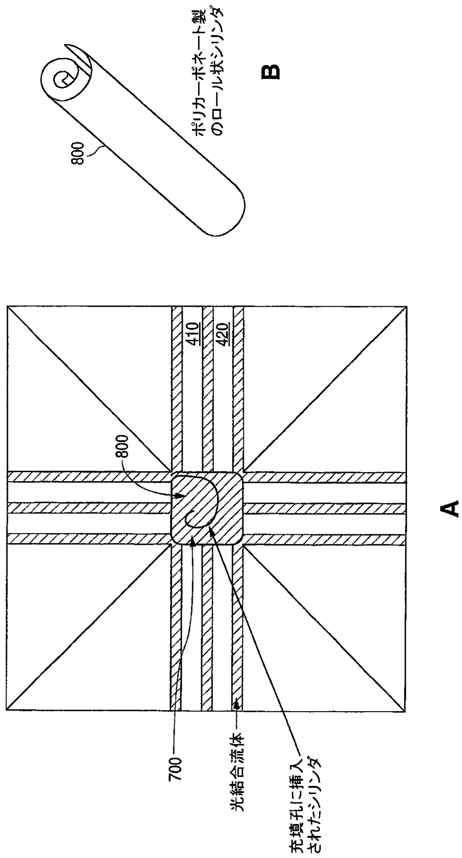
【図６】


212
スペーサボール 600
光結合流体
210

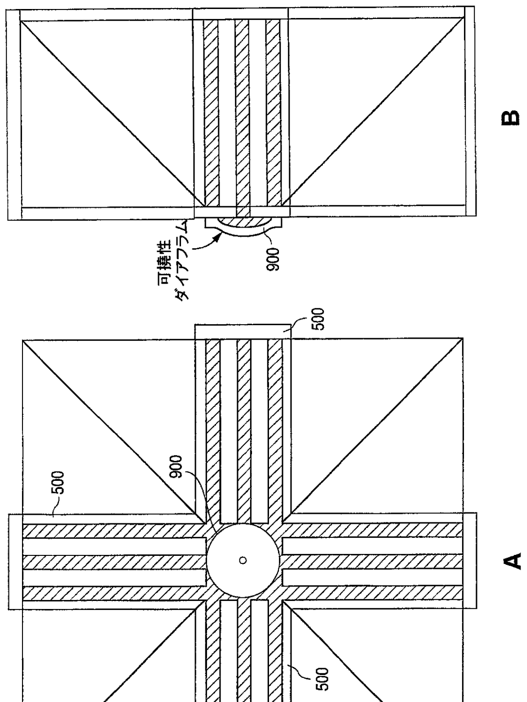
【図７】


液体注入手段
710
中央充填孔
700
プリズム

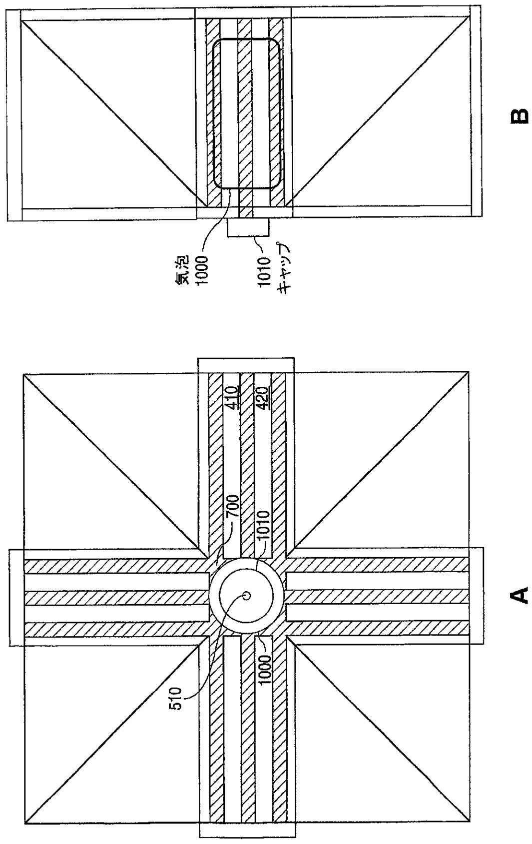
【図８】


ポリカーボネート製
のロール状シリンダ
800
B
410
420
800
A
700
光結合流体
充填孔に挿入
されたシリンダ

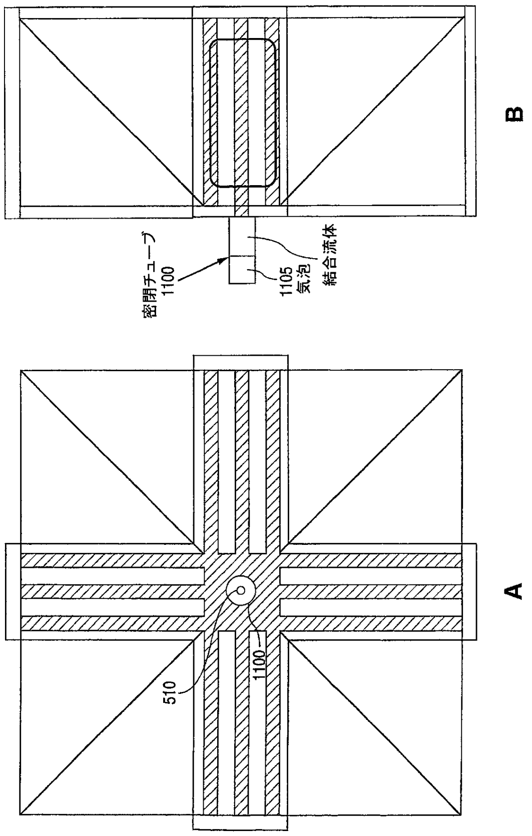
【図９】


B
可撓性
ダイアフラム
900
500
900
500
500
A

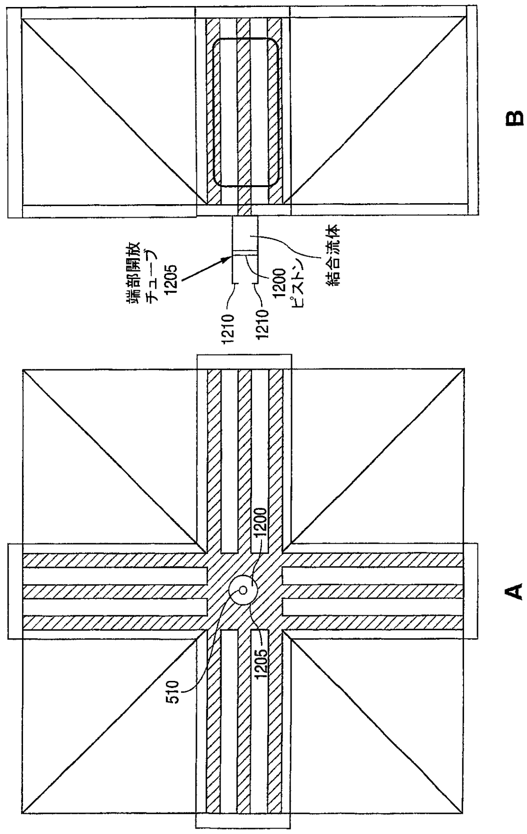
【図１０】


B
気泡
1000
1010
キャップ
410
420
700
1010
510
1000
A

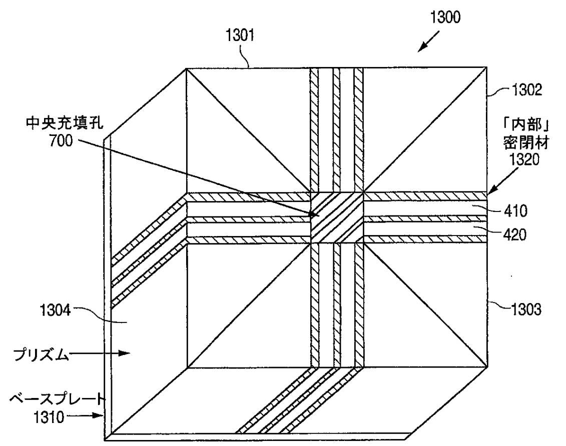
【図１１】



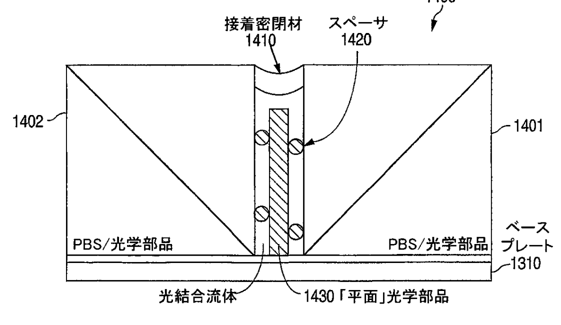
【図１２】



【図１３】



【図１４】



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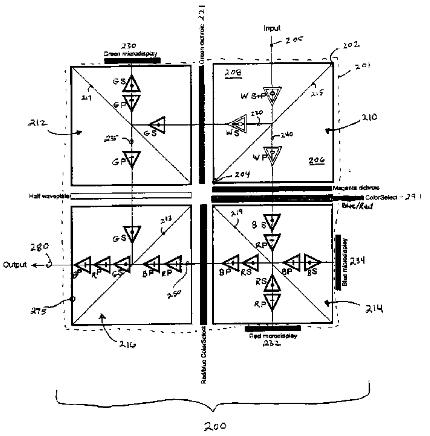
[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR CONFIGURATION AND ASSEMBLY OF A VIDEO PROJECTION LIGHT MANAGEMENT SYSTEM



(57) Abstract: A pathlength matched prism assembly (201) is contructed from Polarizing Beam Splitter optical components (210, 212, 214, 216) having varying degrees of precision by arranging them in pathlength matched positions and fixing them to a baseplate or frame. Gaps between the optical components are sealed by the frame or adhesive sealant. Planar optical elements (221, 291) are inserted between the optical components and space between the optical components and elements is filled with an optical coupling fluid having an index of refraction that closely matches the index of refraction of both components and elements. An expansion compensation device (550) is attached to the prism assembly to compensate for expansion and contraction of the optical coupling fluid. The prism assembly is best suited for use in HDTV and High Definition video projectors.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD AND APPARATUS FOR CONFIGURATION AND ASSEMBLY OF A VIDEO PROJECTION LIGHT MANAGEMENT SYSTEM

BACKGROUND OF THE INVENTION

Field of Invention

The invention relates to Light Management Systems (LMSs). The invention is more particularly related to improvements to LMS and their applications to reflective microdisplay based video projectors.

Discussion of Background

Light Management Systems (LMSs) are utilized in optical devices, particularly projection video devices and generally comprises a light source, condenser, kernel, projection lens, and a display screen, and related electronics. The function of the components of a video projector 100 is explained with reference to Fig. 1. As shown, white light 110 is generated by a light source 105. The light is collected, homogenized and formed into the proper shape by a condenser 115. UV and IR components are eliminated by filters (e.g., hot/cold mirrors 116/117). The white light 110 then enters a prism assembly 150 where it is polarized and broken into red, green and blue polarized light beams. A set of reflective microdisplays 152A, 152B, and 152C are provided and positioned to correspond to each of the polarized light beams (the prism assembly 150 with the attached microdisplays is called a kernel). The beams then follow different paths within the prism assembly 150 such that each beam is directed to a specific reflective microdisplay. The microdisplay that interacts with (reflects) the green beam displays the green content of a full color video image. The reflected green beam then contains the green content of the full color video image. Similarly for the blue and red microdisplays. On a pixel by pixel basis, the microdisplays modulate and then reflect the colored light beams. The prism assembly 150 then recombines the modulated beams into a modulated white light beam 160 that contains the full color video image. The resultant modulated white light beam 160 then exits the prism assembly 150 and enters a projection lens 165. Finally, the image-containing beam (white light beam 160 has been modulated and now contains the full color image) is projected onto a screen 170.

Commercially available prism assemblies include:

•Digital Reflection's Star Prism

•Philip's Trichroic Prism

•IBM's X Prism with 3 PBS

•S-Vision/Aurora System' Off-Axis Prism

•Digital Reflection's MG Prism

•ColorLink's ColorQuad Prism

•Unaxis' ColorCorner Prism

In the prism assembly, pathlengths are precisely matched. That is, the optical distance [] from each of the three microdisplays to an exit face (or output face) 155 of the prism assembly is essentially identical. This allows the microdisplays to be simultaneously in focus at the projection lens. In most currently available prism assemblies, the configuration of the prism assembly consists of precisely formed optical components that have been bonded together. The specific construction techniques by which this is accomplished provides differing advantages and disadvantages.

In some prism assembly configurations, an air gap is introduced between the microdisplays and a face on the prism assembly where the microdisplays are mounted. The air gap is a legitimate approach to accomplish pathlength matching, but has substantial disadvantages. For example, anti-reflection (AR) coatings are needed on the outer surfaces of the microdisplays and the prism assembly faces. The three microdisplays are aligned with respect to each other along all 6 axes of the microdisplay (x, y, z, roll, pitch, and yaw). Alignment is generally performed using mechanical positioners. Once alignment has been accomplished, the problem of maintaining the required precise alignment during the mechanical shock of appliance transport and during the thermal expansion/contraction that occurs while the video projector is in use still remains. In addition, the AR surfaces are exposed to dust, moisture and other atmospheric contaminates that may cause them to degrade. All of these factors reduce video projector performance.

In other prism assembly configurations the microdisplays are bonded to the faces of the prism assembly. Pathlength matching is accomplished by making the prism assembly have “perfect” (very precise) dimensions. Technologies currently being considered for producing these "perfect" dimensions include:

1. Tight Tolerance Component Fabrication

Source components may be fabricated to an extremely tight tolerance. However, such components are not currently available in high volume from vendors within the optics industry. When available, they will be very expensive.

2. Sort Components By Size

Measuring each component in an inventory and matching similarly sized components. The matched components are then used to construct a prism assembly. However, this requires an increased inventory of components from which to select matched sets of components.

3. Utilize Automated Assembly Equipment

The equipment measures the dimensions of each optical component and then actively adjusts their position during the assembly process. Such equipment must be custom designed and is expected to be quite expensive and inflexible.

In all three cases, extremely tight tolerances must be applied to the process used to assemble the optical components into the prism assembly. In all three cases, the outside dimensions of the resulting prism assembly, although having matched pathlengths, can still fall within a wide range. This requires that provisions be made within the video projector to mechanically adjust the position of the prism assembly with respect to the projection lens. Although bonding the microdisplays makes fabrication of the prism assembly more difficult, it has the advantage of eliminating the possibility of eventual misalignment of the microdisplays. In addition, the monolithic construction eliminates exposed surfaces and possible modes of degradation.

The prism assembly configurations each include several different types of plastic and/or glass materials. These disparate materials are bonded together. However, a difficulty arises because each material will have a different coefficient of thermal expansion. Since the prism assembly and its components will inevitably heat and cool during operation, the resulting expansion/contraction of the materials will generate stress (in fact, the process of assembly itself can build mechanical stresses into the prism assembly). Mechanical stress generates optical birefringence. Birefringence effects the polarization of the light beams traveling through the prism assembly and can be visualized on the screen as an undesirable artifact. It is, therefore, important to minimize the occurrence of stress within the prism assembly. One approach to minimize stress is to utilize glass that, in addition to meeting a long list of optical requirements, also has the lowest possible coefficient of stress induced birefringence. An example of one such glass is Schott's SF-57. The use of such a glass improves the situation but does not eliminate the problem.

Based on the considerations discussed above, it should be understood that there are many benefits to mounting the microdisplays directly onto the faces of the prism assembly. However, other various difficulties arise, including the expense of accomplishing the matching of the pathlengths and preparing microdisplays suitable for direct mounting. Furthermore, manufacturers of LMSs have had difficulties with attempts to implement such approaches in high volume manufacturing of any prism assembly configurations. The invention disclosed in this document consists of a prism assembly and construction techniques that can be applied to the construction of most prism assembly configurations (including all of those listed above). It enables inexpensive, high volume manufacturing of pathlength matched prism assemblies allowing the benefits of subsequent attachment of the microdisplays directly onto the faces of the prism assembly.

SUMMARY OF THE INVENTION

The present inventors have realized the need for cost effective pathlength matching and manufacturing techniques of Light Management Systems (LMSs) and particularly the construction of prism assemblies and microdisplay mounting on the prism assembly. The present invention describes a new approach to configuring the prism assembly, one that minimizes the undesirable optical consequences of mechanical stresses that arise within the prism assembly as a result of known construction techniques. The invention includes an inexpensive arrangement and method of constructing a pathlength matched prism assembly. The arrangement and method utilize less expensive, readily available optical components. Optically, the prism assemblies produced by this method are essentially identical and, therefore, can be used in a video projector with little need for mechanical adjustment. The invention can be applied to a wide range of prism assembly configurations and does not compromise other desirable mechanical or optical aspects of prism assembly performance.

In one embodiment, the present invention provides a prism assembly, comprising, a set of optical components arranged in pathlength matched positions, optical coupling fluid in contact with and between each of the optical components, and a frame affixed to each optical component and arranged so as to prevent optical coupling fluid leakage from between the optical components.

In another embodiment the present invention provides a prism assembly comprising, at least two optical components having imprecise dimensions configured to at least one of polarize, beam split, beam reflection and beam combine, said optical components fixed in a position such that pathlengths of beams directed through various paths in the prism assembly and to a focal point are matched, and an optical coupling fluid arranged in said pathlengths so as to contact at least two of the optical components.

In yet another embodiment, the present invention provides a prism assembly, comprising, a set of optical components, a baseplate attached to at least one of the optical components, a seal affixed to at least two of the optical components, and an optical coupling fluid disposed between the sealed optical components.

The present invention also includes a method of constructing a prism assembly, comprising the steps of, fixing a set of optical components to a baseplate, sealing spaces between the optical components, and filling spaces between the optical components with an optical coupling fluid. Various other methods and configurations will become apparent upon a detailed review of the disclosure and drawings as discussed below.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Fig. 1 is a drawing of a Light Management System (LMS) video projector;

Fig. 2 is a drawing of a simplified example kernel illustrating lightpaths and components of one possible configuration of a prism assembly in which the present invention is applied;

Fig. 3 is drawing illustrating a construction technique of an LMS prism assembly according to an embodiment of the present invention;

Fig. 4 is a drawing of liquid coupling of components in an LMS prism assembly according to an embodiment of the present invention;

Fig. 5 is a drawing of top and side views of a frame that holds components of an LMS prism assembly according to an embodiment of the present invention;

Fig. 6 is a drawing of spacers and liquid coupling of components of an LMS prism assembly according to an embodiment of the present invention;

Fig. 7 is a drawing illustrating a coupling fluid filling method according to an embodiment of the present invention;

Fig. 8 is a drawing of an example mechanism utilized to hold prism assembly components according to an embodiment of the present invention;

Fig. 9 is a drawing of a prism assembly equipped with a diaphragm 900 according to an embodiment of the present invention;

Fig. 10 is a drawing of an embodiment of a bladder equipped prism assembly according to an embodiment of the present invention;

Fig. 11 is a drawing of an embodiment of a sealed tube assembly according to an embodiment of the present invention;

Fig. 12 is a drawing of an open air piston arrangement according to an embodiment of the present invention;

Fig. 13 is a drawing of an internally sealed prism assembly according to an embodiment of the present invention; and

Fig. 14 is a close-up of an internal seal of an internally sealed prism assembly according to an embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring again to the drawings, wherein like reference numerals designate identical or corresponding parts, and more particularly to Fig. 2 thereof, there is illustrated a Light Management System (LMS) kernel 200 illustrating lightpaths and components of one possible configuration of a prism assembly in which the present invention is applied. Path length matching and other features are provided based on the present invention. The kernel 200 includes a prism assembly 201, attached microdisplays ("Green" microdisplay 230, "Red" microdisplay 232, and "Blue" microdisplay 234 – the colors are in quotations because the color identifies the content of an image to be displayed, or the light being manipulated, by the individual microdisplay). The kernel is a fundamental component of a video projection system.

The prism assembly 201 comprises a set of optical components, films, and matching elements making a single prism assembly unit. A white light 205 is directed at a Polarizing Beam Splitter (PBS) 210. A polarizing beam splitter thin film 215 perpendicularly polarizes and splits the white light into two beams of polarized light 220 and 240. The lightpaths through the prism assembly are each labeled to indicate the color and polarization of each light path. For example, incoming white light 205 is labeled W S + P (meaning White S and P polarized); light beam 220 is initially labeled WS (meaning white, s-polarized). The s-polarized white light 220 passes through a green dichroic filter 221 (passing green light, making beam 220 a green s-polarized beam (and labeled GS)), and enters a second Beam Splitter 212. A polarizing beam splitter thin film 217 reflects the s-polarized green light to "green" microdisplay 230.

The green microdisplay 230 manipulates the polarized green light according to green content of an image to be displayed. The "green" microdisplay modulates the polarization of the green light on a pixel-by-pixel basis. For example, a no green content pixel of the image to be displayed will be left unaltered, a strong green content pixel of the image to be displayed will have its polarization rotated 90°, and other pixels having varying levels of green content will have their polarization rotated in varying amounts in proportion to the amount of green content. The microdisplay also reflects (reflection or other polarization effects on the light are accounted for by the polarization manipulation of the microdisplay) the green light (now modulated) back toward the polarizing beam splitter thin film 217.

The polarizing beam splitter thin film 217 then reflects some portions and passes other portions of the green light. The amount of light reflected versus passing is based on the amount of modulation performed on the reflected green light. Light with the same polarization as was reflected into the green microdisplay is again reflected. Light that is oppositely polarized (or at least different from a polarization sensitivity of the polarizing beam splitter thin film 217) is passed. Amounts of green light less than the full amount of original green light and more than 0 depend on the amount of modulation (modulation in this example is the amount of polarization rotation).

Beam 235 represents the modulated green light that passes back through the polarizing beam splitter thin film 217 (e.g. green light sufficiently modulated to pass through the polarizing beam splitter thin film 217). Beam 235 enters final Beam Splitter 216 and is reflected off polarizing beam splitter thin film 213. Each of the red and blue components are similarly modulated and passed or reflected from corresponding polarization sensitive materials, to produce beam 250. After reflecting off polarizing beam splitter thin film 213, the modulated green light beam 235 is combined with the red and blue components of beam 250 and then exits the prism assembly through output face 275 as white light 280 containing the image to be displayed.

PBSs 210, 212, 214, and 216 are constructed similarly. In this configuration, each PBS contains 2 optical components (e.g., prisms 208 and 206) and a polarizing beam splitter thin film (e.g. 215). The polarizing beam splitter thin film is, for example, a coating that reflects s-polarized light and passes p-polarized light. Optical elements (e.g., retarders, rotators, etc) are utilized to change the polarization so that desired light beams are either reflected or passed by the polarizing beam splitter thin film so that subsequent polarizing beam splitter thin films may pass or reflect the desired light beams depending on the configuration of optical components and the desired path of each light beam (Fig. 2 is one example configuration and desired paths). For example, when PBS 210 splits the incoming white light into 2 beams, the second beam 240 passes through a wavelength specific retarder (Blue/Red ColorSelect 291) so that PBS 214 can also split beam 240 into component beams directed to each of the red microdisplay 232 and blue microdisplay 234 (without the retarder, the blue component of the white light in beam 240 would remain p-polarized and PBS 214 would then pass the blue light to the red microdisplay 232 instead of reflecting it to the blue microdisplay 234).

The configuration of Fig. 2 illustrates a prism assembly made from 4 similarly constructed PBSs, an advantage over systems utilizing optical components performing a variety of functions (and hence, a variety of differently configured optical components) because the similarly constructed PBSs reduce the number of parts and different functionality of components in a particular optical design. Hence, a corresponding production line benefits from economies of scale, reduced inventory, etc. However, it can also be seen that many different combinations of optical elements can be utilized to make the various beams properly reflect or pass and then re-combine into final light beam 280. Furthermore, the prism assemblies using optical components having a variety of different functions can be constructed. And, as noted above, prism assemblies of all these varieties (different sizes, different shapes, different configurations, etc.) may be constructed using the techniques and processes discussed herein.

Optical components are combined to create the beam splitters. For example, individual prisms 206 and 208 are optical components that are combined to produce the Polarizing Beam Splitter (PBS) 210. Before manufacture of the prism assembly, the beam splitting optical components are built. Prism assembly 201 illustrates four beam splitting optical components, polarizing beam splitters (PBSs) 210, 212, 214, and 216. Each of the polarizing beam splitters (hereinafter referred to as PBSs) contains a polarizing beam splitter thin film (e.g., 215, 217, 219, and 213). Preferably, the polarizing beam splitter thin films are at the diagonal of the beam splitters and extend through the corner as defined by the outside surfaces of the PBS. For example, the polarizing beam splitter thin film 215 extends along the diagonal of 206 and 208 through corners 202 and 204 of the PBS 210. The PBSs may be constructed so that the polarizing beam splitter thin film is on a plane of the diagonal and need not extend through the corners, particularly if light does not pass through the entire range of the diagonal.

The assembly of such PBS is accomplished by the use of optical pathlength matching. Referring to PBS 210, it can be noted that the two optical components (prisms) 206 and 208 need not be exactly the same size (and, consequently, the outside dimensions of the PBS need not meet any specific dimensional requirement). Since there are no specific dimensional requirements for the PBS, optical components with a "loose" mechanical tolerance may be utilized. Such optical components (and prisms used to construct those components) can be produced at modest cost and in high volume by existing vendors of optical components.

The optical components are assembled from the "outside in". As shown in Fig. 3, the two outside surfaces of each of the four PBSs in the prism assembly 201 are accurately held in position by precision alignment corners 300 of an assembly tool 310. For example, outside surfaces of PBS 210 are held in a fixed position determined by alignment corner 300A.

Assembly tool includes an assembly tool base plate 315 to which the precision alignment corners 300 are fixed. Construction of the alignment corners 300A, 300B, 300C, and 300D can be performed using mechanical tooling. The alignment corners are constructed to a tolerance and positioned on the assembly tool base plate such that they precisely fix the outside dimensions of each PBS. Each alignment corner includes a device for securing the PBS in position during assembly. For example, PBS 210 is held tight in alignment corner 300A via vacuum holders 330 and 335. The vacuum holders are connected to vacuum pump 330 via vacuum tube 325. In one embodiment, there is a single vacuum holder in the corner of the alignment corner.

The alignment corners provide the precise dimensional accuracy required to achieve pathlength matching and is accomplished by mechanical tooling rather than expensive tightly toleranced optical components. However, pathlength matching alone does not produce an acceptable prism assembly. Although pathlength matched, because the optical components are of varying non-precise tolerances (different sizes), the PBS do not fit precisely together (e.g., intersection of PBS 210 and 214, and any dichroics or filters placed therebetween, do not fit exactly) and an air gap is introduced between the internal optical surfaces of the PBSs. The air gap itself introduces other problems including refraction and other optical variations that need to be reduced or eliminated.

The present invention reduces the undesirable effects from the imprecisely fit PBSs by coupling the PBSs with a liquid. In one embodiment, all internal optical surfaces of the prism assembly are coupled using a liquid. Fig. 4 is a drawing of liquid coupling of components of an optical assembly according to an embodiment of the present invention. Between adjacent PBSs is a joint that is filled with liquid. The thickness of the liquid filled joints is varied based on variations in size of the individual PBSs (or other optical components utilized in other prism assembly configurations) to maintain the desired exterior dimensions of the prism assembly (e.g., to maintain desired matched pathlengths within the prism assembly). For example, Liquid filled joint J1, the joint between PBS 212 and PBS 216 comprises liquid between the PBSs, the entire joint comprising the liquid coupling fluid 400 in spaces t1, t2, and t3, and dichroics and other optical elements placed between the PBS (e.g., optical element 410 and 420 placed between the PBS). The other optical elements may be, for example, any combination of dichroics or other filters. Accommodation in the liquid coupling fluid will prevent stress from building up in the components.

In one embodiment, a frame, glued to the external surfaces of the prism assembly, is used to contain the liquid and hold the components in place. Fig. 5 is a drawing of top and side views of a frame 500 that holds components of an LMS prism assembly according to an embodiment of the present invention. The frame 500, which can be made of one or several pieces (note that there are not any optical requirements on the frame material), is placed over each of the joints between the PBSs. In this embodiment, the frame 500 comprises 2 side components 500A and 500 C, and 4 edge components 500B. Each side component is a plus sign (+) shaped glass, plastic, acrylic, etc., or other material, each appendage of the plus sign covering a joint, and the middle of the plus sign covering a conjunction of all 4 joints. The edge components 500B cover the edge of each of one of the joints. The top side component 500A includes a fill hole 510 to which fluid may be applied and/or added as needed. A cap (not shown) is used to cap off the fill hole to prevent spillage of the fluid. An air bubble 550 is provided to compensate for liquid expansion/contraction and prevent stress build up on the optical components. The frame 500 is illustrated as a plus sign shape, but may be completely rectangular or any other shape, so long as it covers each joint sufficiently. Glue or other adhesive applied to the frame creates a seal between the frame and the PBSs so as to fully contain the coupling fluid. The glue or other adhesive also fixes the position of the PBSs to the frame to assure nonmovement of the PBSs with respect to each other (maintaining the monolithic nature of the LMS).

Using the adhesive between the frame and PBSs to fix the matched pathlengths is performed by determining the matched pathlength positions of the prism assembly components (e.g., using a tool having corner pieces or other positioning devices to assure the correct optical pathlengths), and then gluing the components (e.g., PBSs) to one or more parts of the frame at those matched pathlength positions. Additional optical elements are then positioned in the joints (e.g., optical elements 410 and 420), the joints are then at least partly filled with optical coupling fluid (liquid coupling fluid), the joints are then capped with a top frame piece, and then the coupling fluid is topped off (except for the air bubble or other expansion air space), and then the fill hole is capped.

The present invention includes various methods and devices to fill the prism assembly with the coupling liquid. For example, Fig. 7 is a drawing illustrating a coupling fluid filling device and method according to an embodiment of the present invention. The coupling liquid is injected into a central fill hole 700 utilizing a syringe filled with coupling fluid. The central fill hole 700 is a center area of the prism assembly, and generally has no optical components therein. However, it is possible that one or more of the optical components may be positioned at least part way into the central fill hole. In one embodiment, the prism assembly is at least partly filled prior to affixing a top portion of the frame onto the prism assembly. If the top portion of the frame is not attached, the coupling fluid may also be applied in an area other than the central fill hole, but filling at the central fill hole is preferred. Also preferable, is injecting the coupling fluid at the bottom of the central fill hole. Capillary action between the optical elements and PBSs in both vertical and horizontal directions will assist the filling process. In other embodiments, the same process occurs with the top portion of the frame in place, in which case the syringe is inserted through the fill hole 510 (cap removed) to the bottom of the central fill hole 700, and the prism assembly is filled with coupling fluid. Other devices including tubes, pumps, or other pouring mechanisms may be used to place the fluid in the central fill hole.

Recognize that, if the components within the prism assembly were to directly touch (e.g., optical element 410 directly touching either optical element 420 or PBS 212), the result could be a visible artifact in an image projected by the prism assembly. The solution to this problem is to assure that a thin layer of liquid exists between the components and or elements of the optical assembly. Many different methods and/or devices may be implemented to assure that a layer of liquid exists between components. For example, the optical elements may be physically separated during filling of the coupling fluid, spacers may be affixed to portions of the frame to separate the elements and PBSs. In one embodiment, spacers are applied between the optical surfaces. Fig. 6 is a drawing of spacers (spacer balls 600) and liquid coupling of components of an LMS prism assembly according to an embodiment of the present invention. The spacers can be glass rods or balls with diameter on the order of thousandths of an inch. The index of refraction of the liquid coupling fluid is chosen to match that of the spacers thus rendering them invisible.

The present invention includes various methods and devices for application of the spacers. In one set of embodiments, the spacers are applied directly to the optical surfaces of the PBSs and/or optical elements. In one embodiment, the spacers are sprayed onto the optical surfaces. Spraying spacers onto optical surfaces may be performed using liquid crystal display manufacturing techniques and machinery. Either wet or dry spacer application may be utilized. In other embodiments, the spacers are suspended in the liquid coupling fluid at least during manufacture. After manufacture of the prism assembly, suspended spaces remain lodged between the optical surfaces and/or settle to a bottom portion of the prism assembly out of the viewing area.

The liquid coupling fluid is an optical coupling fluid selected to have an index of refraction that matches (or closely matches) the index of refraction of the PBSs and any optical elements spaced within the fluid. The index of refraction changes depending on wavelength, and is different for each of the components and elements in the prism assembly. Typical values are 1.52 for plastic elements, and 1.71 for glass components. The optical coupling fluid generally preferred to have an index of refraction in the 1.50-1.85 range. A 1.6 index of refraction optical coupling fluid has worked well in experiments carried out by the inventors. Similarly, in the embodiments using spacers, the optical coupling fluid is chosen to have an index of refraction preferably matching each of the PBSs, optical elements, and spacers as closely as possible. Matching the index of refraction can be done by splitting the difference between the index of refraction of the optical components and elements. Another method would be to perform an impedance matching type of arithmetic (e.g., taking the square root of the sum of the squares of the index of refraction of each optical component/element). However, the present inventors note that selection of any index of refraction between the high and low index of refraction of the optical components and elements provides better matching than any other embodiments of the pathlength matched prism assembly, including the gel, cured epoxy, and air filled embodiments discussed elsewhere herein. The chosen index of refraction of the coupling fluid may also be weighted toward matching component interfaces that occur more frequently in the prism assembly. In one embodiment, the index of refraction of the coupling fluid matches the index of refraction of the spacers.

Important properties for the coupling fluid are toxicity, flammability, yellowing propensity, chemical properties, and cost. Toxicity and flammability are safety considerations, the product is preferably non-toxic and non-flammable. Also, the optical coupling fluid, to be practical, needs to be resistant to yellowing, particularly under intense light and heat conditions. The optical coupling fluid has to have chemical properties that do not react with other optical elements, components, and parts of the prism assembly. And, to be commercially practical, the optical coupling fluid needs to be relatively inexpensive and readily available. In one embodiment, the optical coupling fluid is, for example, mineral oil. Many different types and properties of optical coupling fluid are commercially available (e.g., Cargille Corp makes many different types of index matching fluid).

In one embodiment, the optical coupling fluid is a UV curing adhesive, which, when cured, makes a solid prism assembly, the cured adhesive coupling the optical elements/components without fluids. However, the liquid filled embodiments have better index of refraction matching than commercially practical UV curing adhesive, so the liquid filled embodiments are preferred. In another embodiment, optical coupling is performed by inserting an optical coupling gel between the various components/elements of the prism assembly. NYE corporation makes one such gel (matching gel). In yet another embodiment, the coupling material is air, or another gas is utilized as a coupler between the optical components and elements. In the air-filled embodiment, anti-reflection coating are places on the surfaces of the optical elements and components to eliminate or reduce reflections.

Note that variations of the assembly techniques described herein can be applied to any of the prism assembly configurations discussed in this document.

There are several other advantages offered by the configuration and manufacturing method described above. These include the following:

Several prism assembly configurations include polarization-rotating component(s) (rotators) (e.g., rotating beam 235 after being passed by polarizing beam splitter thin film 217 so it is then reflected by polarizing beam splitter thin film 213). Rotators are generally constructed of layers of polycarbonate plastic bonded together. In prior systems, the adhesive needs to be able to bond the polycarbonate plastic of the rotator to the glass of the prism assembly components. The common solution to this problem is to purchase the polarizing rotator from the vendor in the form of a “sandwich”. In "sandwich" form, the rotator has been bonded between two cover glasses. The cover glasses make it easier for the prism assembly manufacturer to bond the rotator into the prism assembly (e.g., bonding between surfaces of adjacent cover glasses). However, compared to the polycarbonate rotator itself, the sandwich may be available only in limited supply and is more expensive. In contrast, in the present invention, The liquid coupling method allows the direct use of the inexpensive, readily available polycarbonate component. Since with liquid coupling the polycarbonate is not bonded with adhesive, this class of problems is eliminated.

The precise outside dimensions of the prism assembly obtained using the new manufacturing method not only allow direct mounting of the microdisplays onto the prism assembly, but also allows for the use of precision (or fixed) mounting points for mounting the completed kernel (prism assembly with microdisplays attached) into the device in which it is to be used (e.g., light engine). The use of precision or fixed mounting points reduces or eliminates the need for a physical adjustment mechanism and procedure when mounting the kernel into the light engine.

Conventional prism assemblies generally utilize a series of glue cure steps. As the prism assembly grows in size and complexity, it becomes progressively more difficult to cure the adhesives due to the absorption of light by the glass and/or the optical properties of the components. Liquid coupling as provided by the present invention eliminates this problem and can greatly reduce the time required for prism assembly.

The present invention includes a device and method to hold the optical elements (e.g., optical elements 410 and 420) in place. The optical elements are also generally referred to as flat components because they are generally rectangular in shape and flat (having a thin width). However, the present invention may be practiced using different shapes and widths of the optical components.

One concern at any time, including manufacture, shipping, storage, and/or during actual use is the potential movement of optical components in the coupling fluid. Movement towards the central fill hole 700 could potentially leave the moved component (or parts of the moved component) out of the optical path. The present invention provides for placing a spacer device in the central fill hole 700 to hold the flat components in a stable general location. Fig. 8 is a drawing of an example spacer device 800 utilized to hold optical components according to an embodiment of the present invention. In the illustrated embodiment, the spacer device 800 is a sheet of polycarbonate rolled into a tight cylinder. The spacer device 800 is inserted into the central fill hole 700. Once in place, the cylinder will "unroll" and press on the components so as to keep them out of the central hole.

As previously discussed an air bubble may be left inside the prism assembly to account for expansion of the various components. One problem with expansion of the components is that the components expand at different rates. As the optical coupling fluid expands, so does the optical components of the prism assembly. however, the expansion of the liquid and optical components is at different rates (differential expansion). In most cases, the optical coupling fluid expands at a higher rate than the optical components. Without the air bubble, an amount of stress is applied against the optical components by the expanding fluid. Without the air bubble, this stress can cause an undesirable amount of stress induced birefringence effecting the various light beams passing through the optical components of the prism assembly as the liquid coupling fluid expand.

Referring back to Fig. 5, an air bubble 550 is illustrated. The air bubble 550 is permanently maintained within the prism assembly once the fill hole 510 is capped. In Fig. 5, the "frame" elements (500A, 500B, and 500C) on the outside of the prism assembly serve both to contain the liquid and to hold the prism assembly components rigidly in space.

In the example embodiment of Fig. 5, the volume within the prism assembly surrounded by frame 500 is occupied by glass of the prism assembly components (e.g., PBSs), optical elements, and the optical coupling liquid. As the temperature of the prism assembly rises (as it will during operation) the linear and volume dimensions of all components increase. However, at least partly due to the fact that the coefficient of thermal volumetric expansion of the optical coupling liquid is considerably higher than that of the glass and other materials, when the temperature rises, the volume of the liquid expands faster that that of the glass "container" (optical components and frame bounding the liquid). In addition to the undesirable optical effects, excessive stress caused by this differential expansion could potentially cause the bonded components to separate. The air bubble 550 is one way to accommodate the effects of differential expansion and avoid the build up of stress.

Fig. 9 is a drawing of a prism assembly equipped with a diaphragm 900 according to an embodiment of the present invention. The diaphragm 900 is constructed of a flexible material such as rubber, plastic, or another material with sufficient strength and flexibility to accommodate the expanding fluid and thereby relieve stress. The diaphragm 900 flexes as the volume of liquid increases or decreases. Preferably, the diaphragm 903 is circular and affixed over the fill hole 510 using an adhesive. However, other shapes and attachment mechanisms may be utilized (e.g., the flexible material fitted under a ring clipped to the frame around the fill hole).

Fig. 10 is a drawing of an air bladder 1000 equipped prism assembly according to an embodiment of the present invention. In one embodiment, the frame 500 is capped (e.g., cap 1010), and a bladder is inserted inside the optical assembly. The bladder expands and contracts as the volume of liquid decreases and increases.

The air filled bladder 1000 is inserted into the fill channel (central fill hole 700). The volume of the bladder can increase or decrease to accommodate volumetric changes in the coupling liquid. In alternative embodiments, the bladder may be filled with any suitably compressible material (e.g., gas, liquid, solid, or combination thereof). The bladder 1000 can also serve to assist in holding those components in place that are not glued to the frame (e.g., the "flat" components (e.g., 410, 420)located between the polarized beamsplitting cubes). When configured to assist in holding the "flat" components in place, spacers such as polycarbonate roll 800 are not needed.

Fig. 11 is a drawing of an embodiment of a sealed tube 1100 assembly according to an embodiment of the present invention. A sealed tube 1100 is attached to the fill hole 510. A portion of the sealed tube 1100 contains an air bubble 1105. The air bubble 1105 will enlarge or shrink to accommodate expansion or contraction of the liquid within the prism assembly. In this approach, similar to the air bubble only approach discussed above, it is important to understand the orientation of the prism assembly in the light engine application. The reason being that the air bubble 1100 will migrate to the highest point within the prism assembly. It is therefore necessary to design the system such that the end of the tube is a high point. The tube may be configured with an elbow or other structure to direct the air bubble to an appropriate location. In the case of the air bubble only approach, it is therefore important that the high point of the prism assembly (high point of fluid in the prism assembly) is not at a point in of the optical paths of the prism assembly.

Fig. 12 is a drawing of an open air piston 1200 arrangement according to an embodiment of the present invention. An open ended tube 1205 is attached to the fill hole 510. A sliding piston 1200 fits snugly inside the open ended tube. As the optical coupling liquid expands with increasing temperature, the piston 1200 slides outward within the open ended tube. As the optical coupling liquid shrinks with decreasing temperature, surface tension (and/or pressure variance between the inside and the outside of the prism assembly) causes the piston to slide inward within the open ended tube 1205. In one embodiment, the open ended tube is longer than a predicted maximum expansion of the optical coupling fluid. In one alternative, stops 1210 are positioned inside the open ended tube to prevent the piston from reaching the open end of the tube 1205. In another alternative, the stops 1210 are electrodes connected to an emergency shut-off circuit, and the piston 1200 has a conductive material on its outer surface. When the piston contacts stops 1210, the light engine to which the prism assembly is installed is shut down at least until the prism assembly is sufficiently cooled to disengage piston 1200 from the stops 1210. As with all the embodiments listed herein, the open ended tube may be combined with one or more other embodiments (e.g., air bladder) to provide stress relief to compensate for the expanding and contracting optical coupling fluid.

Each of the above embodiments have an external frame (e.g., frame 500 – external to the optical components of the prism assembly) that seals the prism assembly and contains the optical coupling fluid (and include any necessary attachments for any of the stress relief features discussed above). The frame also provides structural strength to the prism assembly. However, the present inventors have also realized the need for a compact arrangement for sealing the optical coupling fluid. The compact arrange then allows for the prism assembly to be utilized in a wider variety of optical applications, including different LCoS based video projection systems.

Furthermore, any newly designed and/or previously existing light engine systems can be fitted with a fluid coupled prism assembly. In new designs, fitting the liquid coupled prism assembly may be performed by fitting mounts within the projection system to accommodate one or more liquid coupled prism assembly sizes. However, in the case of retrofit systems (fitting liquid filled prism assemblies to previously sold projection systems and/or fitting liquid coupled prism assemblies to new projection system of a previous design); physical accommodation of the liquid coupled prism assemblies may not be so easily accomplished. That is, the physical size and shape of a fluid coupled prism assembly may not allow it to directly fit into the position provided for a conventional prism assembly within an existing light engine. The modifications of the light engine required to accommodate a fluid coupled prism assembly may be difficult, expensive or, in an extreme case, not possible. Therefore, by providing a fluid coupled prism assembly that is sealed and provides structural strength and has external dimensions that are similar to that of an equivalent conventional prism assembly, that prism assembly could be used as a drop in replacement for a conventional prism assembly in any light engine design. The invention disclosed in this document is such a means.

For these reasons, the present inventors have also developed an internally sealed prism assembly that seals and provides structural integrity to a liquid filled prism assembly.

Fig. 13 is a drawing of an internally sealed prism assembly 1300 according to an embodiment of the present invention. The internally sealed prism assembly 1300 includes a baseplate 1310 and at least one internal seal 1320 between optical components of the prism assembly. Comparing this embodiment to the previous configurations, most features of the external frame are absent except the base plate 1310 (the base plate being a feature common to both the conventional and fluid coupled prism assembly configurations). The base plate 1310 provides a secure, firm surface for attaching the PBSs 1301-1304. As illustrated in Fig. 13, the internal seal is fitted between optical elements 410 and 420, between optical element 410 and PBS 1302, and between optical element 420 and PBS 1303.

The internal seal extends downward fro??the top of the optical elements/PBSs a short distance (e.g., 1 mm) to produce a seal that maintains the optical coupling fluid installed into the prism assembly. In one embodiment, the internal seal also overlaps the tops of the optical elements 410 and 420, such that the seal covers the exposed surfaces of the optical elements, but preferably does not extend beyond the outer surface of the PBSs. In depth, the seals seeps between the optical elements/PBSs to a prescribed sealing depth (e.g., 1 mm).

Fig. 14 is a close-up of an internal seal of an internally sealed prism assembly 1400 (part view) according to an embodiment of the present invention. In Fig. 14, 2 PBSs 4101 and 1402 have an internal seal 1410 between them. The internal seal may be described as a "picture frame" between the PBS elements. The adhesive does not extend beyond the outer surface of the prism assembly. Preferably, the internal seal is an adhesive agent that not only seals the prism assembly, preventing leakage of the optical coupling fluid, but may also provide additional rigidity to the entire structure. The adhesive may be, for example a 1 or 2 part epoxy or a UV cured adhesive that both hardens and seals.

Alternatively, the adhesive seal may be a pliant adhesive such as silicone based adhesives. However, flexing of the prism assembly can become an issue if non-hardened sealant is utilized. While the bottom plate of the frame provides enough rigidity that pliant adhesives may be acceptable in some applications, a top plate (on the side of the prism assembly opposite the base plate) in addition to the base plate adds enough rigidity that pliant adhesives are fully acceptable in most all applications.

Fig. 14 also illustrates an optical element ("Planar" optical component 1430) separated by spacers 1420. The optical element is shorter than a bottom height of the adhesive sealant. The optical element is representative and may in fact be several optical elements also separated from the PBSs and each other via additional spacers. The "planar" optical components 1410 are items such as dichroics, reflective polarizers and wavelength specific retarders contained between the PBSs and suspended in the optical coupling liquid. The planar components are spaced from the glass surfaces by use of spacer elements as discussed previously.

Penetration (the prescribed sealing depth) of the adhesive 1410 is confined to a region out of the optical path. The base plate 1310 provides the required rigidity to the prism assembly.

As explained above, the principle advantages of the disclosed liquid coupled prism assembly techniques and configurations include the ability to use less expensive, low tolerance glass components, and the ability to fabricate a prism assembly with "perfect" outside dimensions and in so doing, enabling the attachment of microdisplays directly to the prism assembly. In turn, the latter provides several advantages the foremost being that the resulting monolithic assembly will remain in a alignment under a wide range of conditions.

An alternative means by which these advantages can be obtained is to utilize the "build from the outside in" procedure described previously but, rather than filling the prism assembly with an optical coupling liquid, leaving the assembly empty therefore "filling" with air. However, in this approach, it will be necessary to coat all surfaces now exposed with an anti-reflection thin film (AR coatings) to suppress reflections. The expansion port is not required in this configuration. In some applications it may be possible to also omit the side rails of the frame (e.g., 500B) and possibly the top (500C).

In yet another alternative, the prism assembly is filled with an epoxy that cures. Preferably the cured epoxy has an index of refraction that closely matches the index of refraction of the PBSs and optical elements utilized. In still yet another embodiment, a gel substance may also be used to fill the joints between adjacent PBSs. Again, preferably, the gel has an index of refraction that approximates that of the other parts of the prism assembly. An example gel that could be utilized is manufactured by NYE Corporation.

In describing preferred embodiments of the present invention illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the present invention is not intended to be limited to the specific terminology so selected, and it is to be understood that each specific element includes all technical equivalents which operate in a similar manner. For example, when describing a spacer device constructed of rolled polycarbonate, any other equivalent device, such as a geometrically shaped (square, 24 angle, pentagon, hexagon, etc) or other shape roll of polycarbonate or any other material or any other device having an equivalent function or capability, whether or not listed herein, may be substituted therewith. Furthermore, the inventors recognize that newly developed technologies not now known may also be substituted for the described parts and still not depart from the scope of the present invention.

The present invention is mainly described in conjunction with a LMS that utilizes a microdisplay that operates by rotating polarization of individual pixels. However, based on the description provided herein, it should be understood that the present invention may be practiced in devices with other types of microdisplays (e.g., scattering, absorption, diffraction based microdisplays), or in optical devices constructed without microdisplays.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

WHAT IS CLAIMED IS:

1. A prism assembly, comprising:

a set of optical components arranged in pathlength matched positions; and

a frame affixed to each optical component and arranged so as to prevent optical coupling fluid leakage from between the optical components.

2. The prism assembly according to Claim 1, further comprising an optical coupling substance in contact with and between each of the optical components.

3. The prism assembly according to Claim 2, wherein said optical coupling substance is a liquid.

4. The prism assembly according to Claim 2, wherein said optical coupling substance is a gas mixture.

5. The prism assembly according to Claim 4, wherein said gas mixture is air.

6. The prism assembly according to Claim 5, wherein said optical components include at least one anti-reflection coating on a surface of the optical components.

7. The prism assembly according to Claim 2, wherein said optical coupling substance is a gas.

8. The prism assembly according to Claim 2, wherein said optical coupling substance is a gel.

9. The prism assembly according to Claim 2, wherein said optical coupling substance is a UV cured adhesive.

10. The prism assembly according to Claim 1, wherein said pathlength matched positions are physical pathlength matched.

11. The prism assembly according to Claim 1, wherein said optical components comprise at least one polarizing beam splitter.

12. The prism assembly according to Claim 1, further comprising a set of corner blocks configured to fix placement of outside surfaces of the optical components.

13. A prism assembly comprising:

at least two optical components having imprecise dimensions configured to at least one of polarize, beam split, beam reflection and beam combine, said optical components fixed in a position such that pathlengths of beams directed through various paths in the prism assembly to a focal point are matched; and

an optical coupling fluid arranged in said pathlengths so as to contact at least one of the optical components.

14. The prism assembly according to Claim 13, wherein the imprecise dimensions of the optical components are such that said pathlengths are not matched to a precision that if the optical components were fitted together, said pathlengths would not provide a focus to beams directed through the prism assembly and then recombined before a focal point.

15. A prism assembly, comprising:

a set of optical components;

a baseplate attached to at least one of the optical components;

a seal affixed to at least two of the optical components; and

an optical coupling fluid disposed between the sealed optical components.

16. The prism assembly according to Claim 15, wherein said seal comprises an adhesive connecting internal optical surfaces between adjacent sealed optical components.

17. The prism assembly according to Claim 16, further comprising a set of at least one planar optical components disposed between at least one of the adjacent sealed optical components.

18. The prism assembly according to Claim 17, further comprising spacers contained in the optical coupling fluid.

19. The prism assembly according to Claim 17, where at least one of the planar optical components divides the seal between the adjacent optical component.

20. The prism assembly according to Claim 15, wherein said set of optical components comprises 4 Polarizing Beam Splitter (PBS) components arranged in a rectangular shape;

said seal encloses the interior optical surfaces of the PBSs to form an optical coupling fluid tight container.

21. The prism assembly according to Claim 20, wherein the rectangular shape is a square.

22. The prism assembly according to Claim 20, wherein the rectangular shape comprises a pathlength matched optical paths through the prism assembly for 3 distinct light beams.

23. The prism assembly according to Claim 22, wherein the 3 distinct light beams are red, green, and blue, each of which may contain other parts of the spectrum at different portions of the corresponding pathlength.

24. The prism assembly according to Claim 15, further comprising an air bubble in the optical coupling fluid.

25. The prism assembly according to Claim 24, wherein said air bubble is outside of optical pathlengths through the prism assembly.

26. The prism assembly according to Claim 15, further comprising a bladder disposed in the optical coupling fluid.

27. The prism assembly according to Claim 26, wherein said bladder is filled with air.

28. The prism assembly according to Claim 26, wherein said bladder is filled with a flexible expansion/contraction material.

29. The prism assembly according to Claim 26, wherein:

said set of optical components comprises 4 Polarizing Beam Splitter (PBS) components arranged in a rectangular shape with one PBS at each corner, a pathlength matching space between each adjacent PBS, and a central fill area centrally located between each PBS; and

said bladder is disposed in the central fill area outside optical pathlengths through the prism assembly.

30. The prism assembly according to Claim 26, wherein:

said set of optical components comprises 4 Polarizing Beam Splitter (PBS) components arranged in a rectangular shape with one PBS at each corner, a pathlength matching space between each adjacent PBS, and a central fill area centrally located between each PBS; and

said prism assembly further comprises a cap configured to cover and seal the central fill area.

31. The prism assembly according to Claim 15, wherein the optical coupling fluid is maintained between the optical components, the seal, and the baseplate.

32. The prism assembly according to Claim 15, further comprising a tube having an open end and a closed end, the open end in contact with the optical coupling fluid; and

an air bubble disposed inside the tube.

33. The prism assembly according to Claim 15, further comprising:

an open ended tube having a first end and a second end, the first end in contact with the optical coupling fluid, and the second end open to the exterior of the prism assembly;

a sealed movable piston disposed in said tube, said piston configured to move because of expansion and contraction of the optical coupling fluid.

34. The prism assembly according to Claim 33, further comprising at least one stop configured to limit motion of the piston.

35. The prism assembly according to Claim 15, further comprising a diaphragm disposed and sealed over an opening to the optical coupling fluid.

36. A High Definition Monitor comprising:

a white light source;

a set of reflective microdisplays;

a prism assembly configured to separate white light from the white light source into component light beams and direct each component light beam to one of the reflective microdisplays and then recombine the reflected component light beams to an output beam;

a lens for projecting the output beam; and a screen for displaying the projected output beam when said prism assembly comprises a set of pathlength matched optical components and coupling fluid interspersed between the optical components.

37. The High Definition Monitor according to Claim 36, wherein the component light beams are red, green, and blue.

38. The High Definition Monitor according to Claim 36, wherein said High Definition Monitor is part of an HDTV.

39. The High Definition Monitor according to Claim 36, further comprising electronics to control the microdisplays.

40. The High Definition Monitor according to Claim 36, wherein the coupling fluid comprises an optical coupling fluid having an index of refraction equivalent to an index of refraction of the optical components.

41. The High Definition Monitor according to Claim 36 beam splitter.

42. The High Definition Monitor according to Claim 36, wherein said optical components comprise at least one of a polarizing beam splitter, a polarization sensitive reflective beam splitter, and a one way reflective beam combiner.

43. A method of constructing a prism assembly, comprising the steps of:
fixing a set of optical components to a baseplate;
sealing spaces between the optical components; and
filling spaces between the optical components with an optical coupling fluid.

44. The method according to Claim 43, wherein the optical coupling fluid is at least one of mineral oil and other fluid having an index of refraction within 25% of the index of refraction of the optical components.

45. The method according to Claim 43, suspending spacers in the optical coupling fluid.

46. The method according to Claim 43, further comprising the steps of coating planar optical components with the optical coupling fluid; and inserting the planar optical elements between the optical components.

47. The method according to Claim 43, wherein said step of fixing comprises the steps of:

arranging the optical components in a pathlength matched configuration; and attaching the pathlength matched configuration to the baseplate.

48. The method according to Claim 47, wherein said step of attaching comprises glueing the pathlength matched configuration to the baseplate.

49. The method according to Claim 43, further comprising the step of:

installing an expansion compensation device in the prism assembly.

50. The method according to Claim 49, wherein said expansion compensation device comprises a bladder filled with a flexible substance.

51. The method according to Claim 49, wherein said expansion compensation device comprises an open ended tube having a slide piston.

52. The method according to Claim 49, wherein said expansion compensation device comprises a flexible diaphragm sealed over an opening into the prism assembly optical coupling fluid.

53. The method according to Claim 49, wherein said expansion compensation device comprises a tube having an open end in contact with the optical coupling fluid and a closed end holding an air bubble.

54. The method according to Claim 49, wherein said expansion compensation device comprises an air bubble disposed in the optical coupling fluid.

55. The method according to Claim 43, further comprising the step of inserting planar optical elements between the optical components.

56. The method according to Claim 43, further comprising the step of inserting planar optical elements between the optical components;

wherein said step of filling comprises filing spaces between the optical components with an optical coupling fluid having spacers suspended in the optical coupling fluid.

57. The method according to Claim 43, wherein said optical components comprise 4 Polarizing Beam Splitter (PBS) devices arranged in a pathlength matched rectangular shape.

58. The method according to Claim 43, wherein said step of sealing comprises fixing a frame around each of the optical components.

59. The method according to Claim 43, wherein said step of sealing comprises applying adhesive between each of the optical components.

60. The method according to Claim 43, wherein said step of filling spaces comprises injecting optical coupling fluid using any of a syringe or other tub based injection system.

61. The method according to Claim 47, wherein said step of arranging the optical components comprises setting the optical components in a tool having blocks that set outside dimensions of the prism assembly.

62. The method according to Claim 61, wherein said blocks comprise corner pieces, each corner piece configured to position outside surfaces of one of the optical components.

63. The method according to Claim 61, wherein at least one of said blocks include an airduct configured to apply a vacuum to the optical component set in the airducted block and hold the optical component firmly against the airducted block.

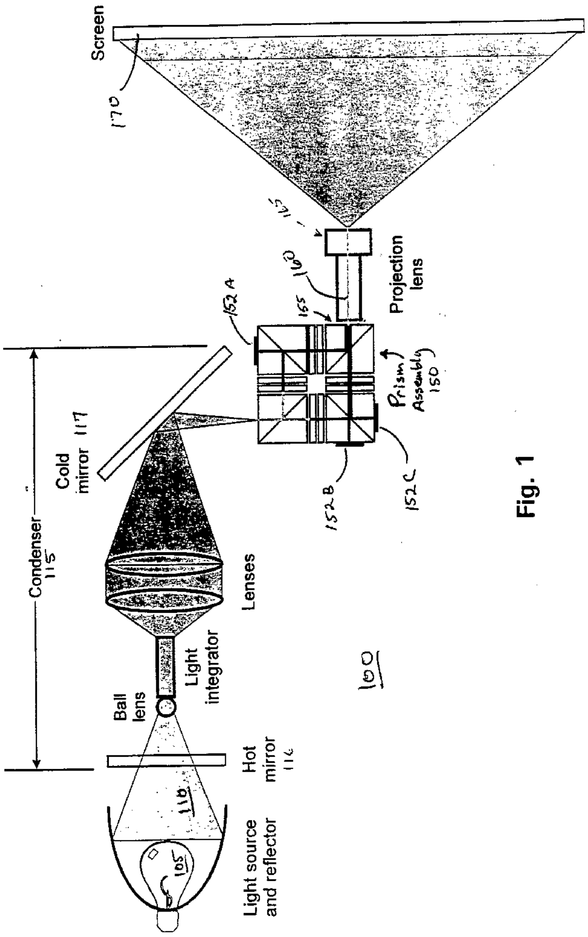
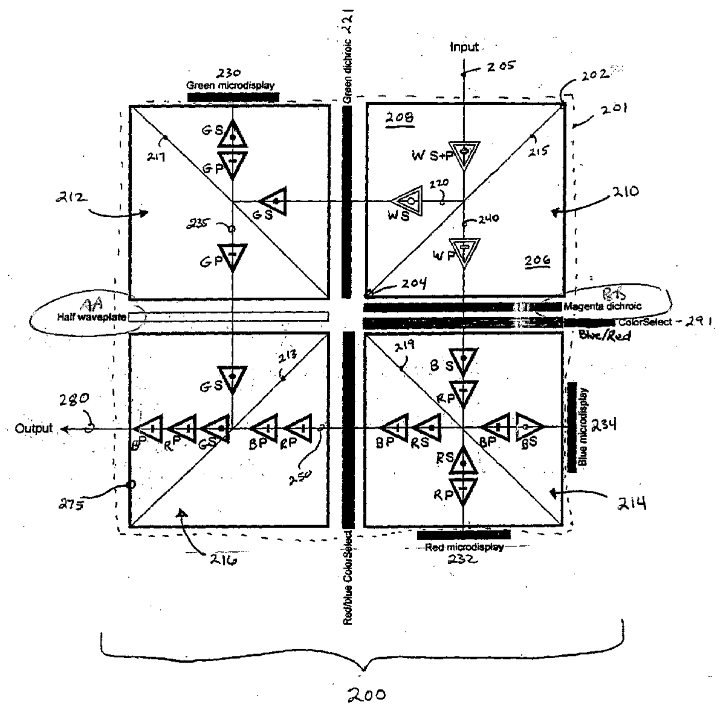

Screen
170
Projection lens
160
155
152A
Prism Assembly 150
152B
152C
Cold mirror 117
Condenser 115
Lenses
Light integrator
Ball lens
Hot mirror 116
110
105
Light source and reflector
100

Fig. 1

Fig. 2


Input
205
202
201
230
Green microdisplay
Green dichroic 221
208
W S+P
215
210
212
217
G S
G P
220
W S
G S
240
235
G P
W P
206
204
AA
Half waveplate
Magenta dichroic
ColorSelect - 291
Blue/Red
219
213
B S
R P
G S
280
Output
B P
R P
G S
B P
R P
B P
R S
B P
B S
234
Blue microdisplay
250
R S
R P
275
214
216
Red/blue ColorSelect
Red microdisplay
232
200

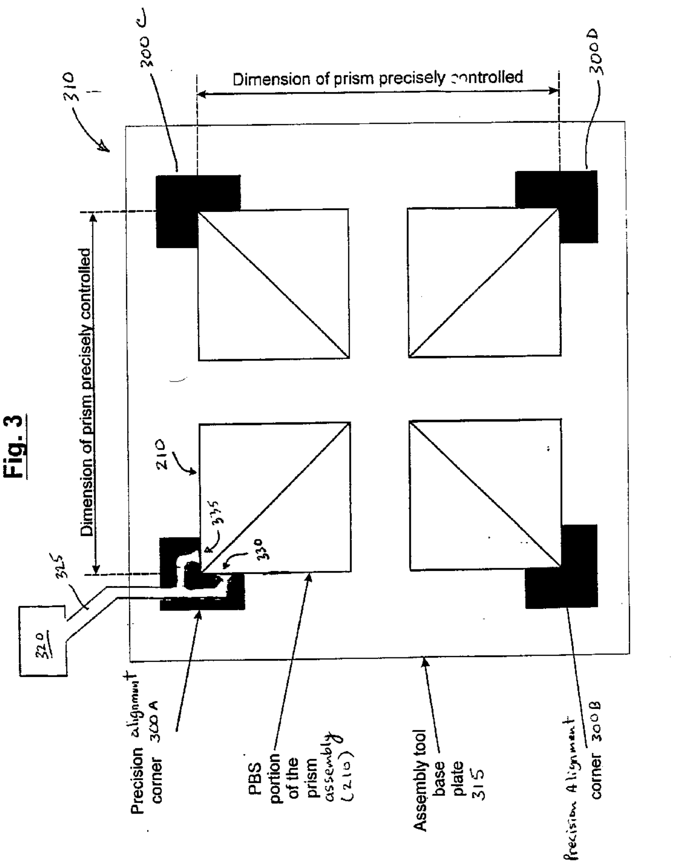

Dimension of prism precisely controlled
Dimension of prism precisely controlled
310
300 C
300 D
210
335
330
325
320
Precision alignment corner 300 A
PBS portion of the prism assembly (210)
Assembly tool base plate 315
Precision Alignment corner 300 B

Fig. 3

Fig. 4

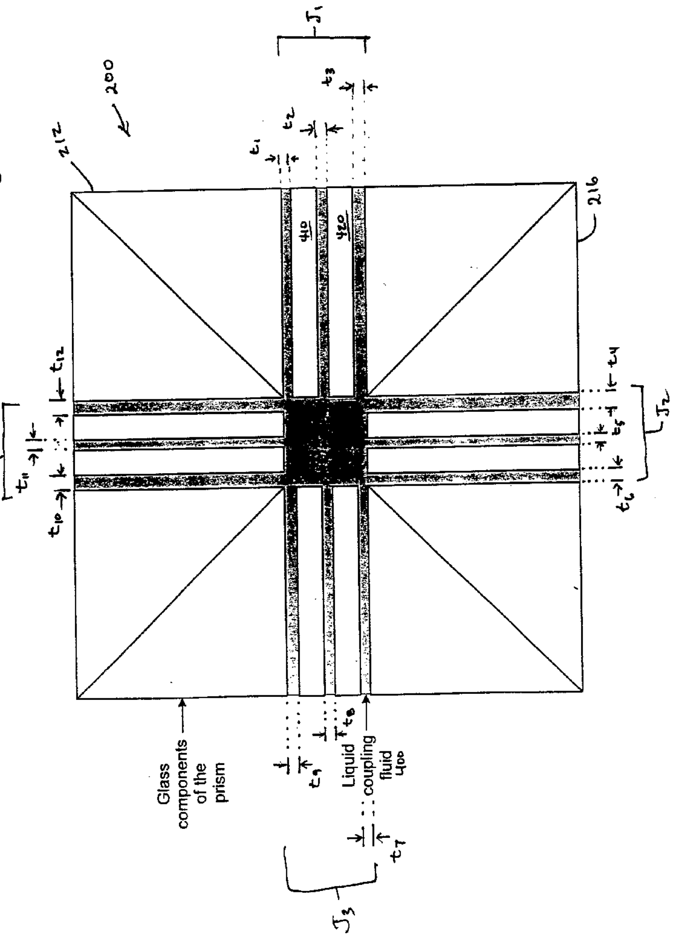

200
212
216
Glass components of the prism
Liquid coupling fluid 400

Fig. 5

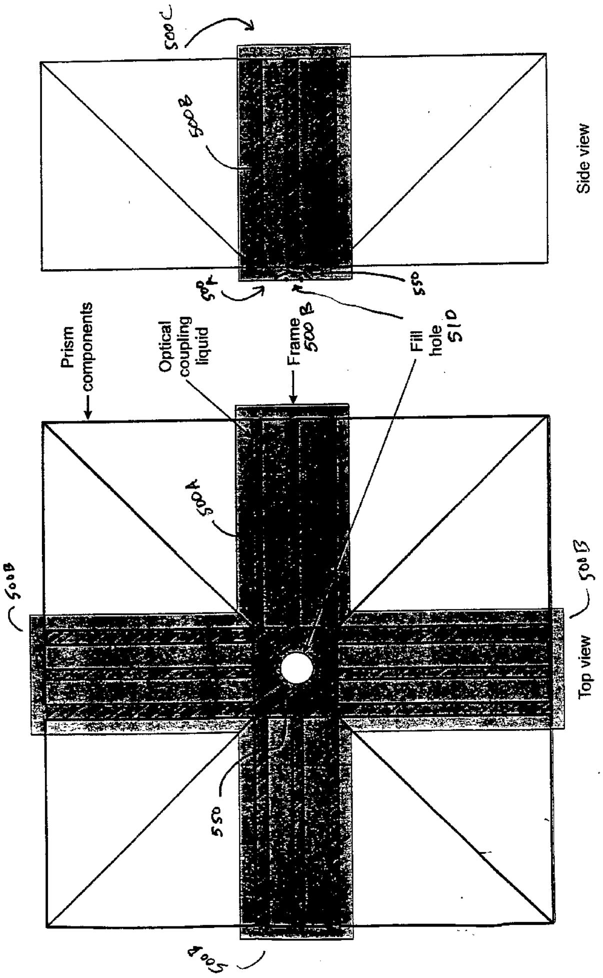

Prism components
Optical coupling liquid
Frame 500 B
Fill hole 510
Side view
Top view
500C
500B
500A
550
501B

Fig. 6

Dimensions are not to scale.
There are numerous spacers distrubuted in an irregular patern.
The index of refraction of the optical couling liquid matches that of the spacer balls.

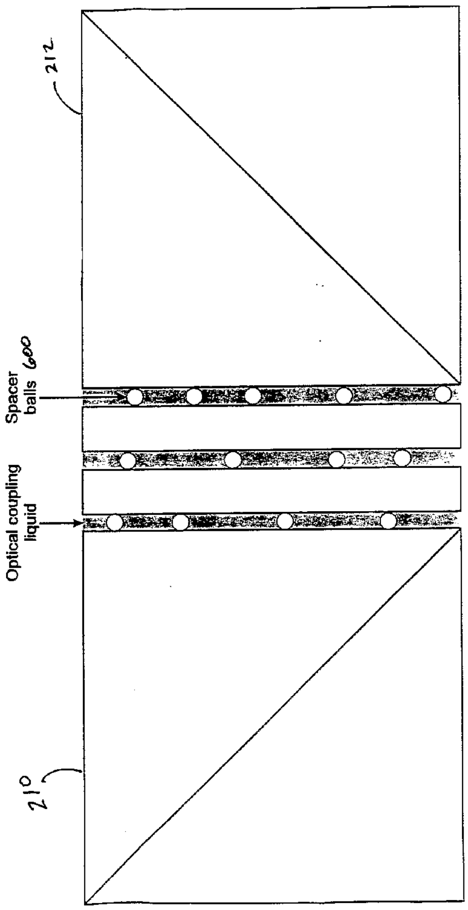


Fig. 7

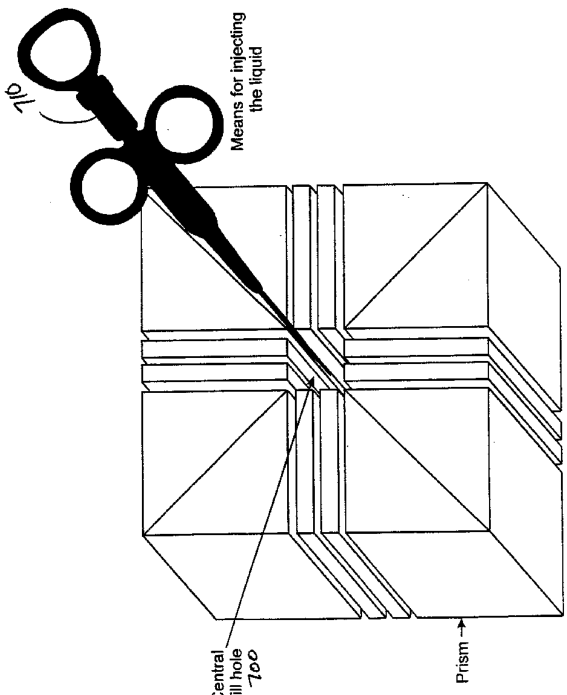

Means for injecting the liquid
710
Central fill hole 700
Prism

Fig. 8

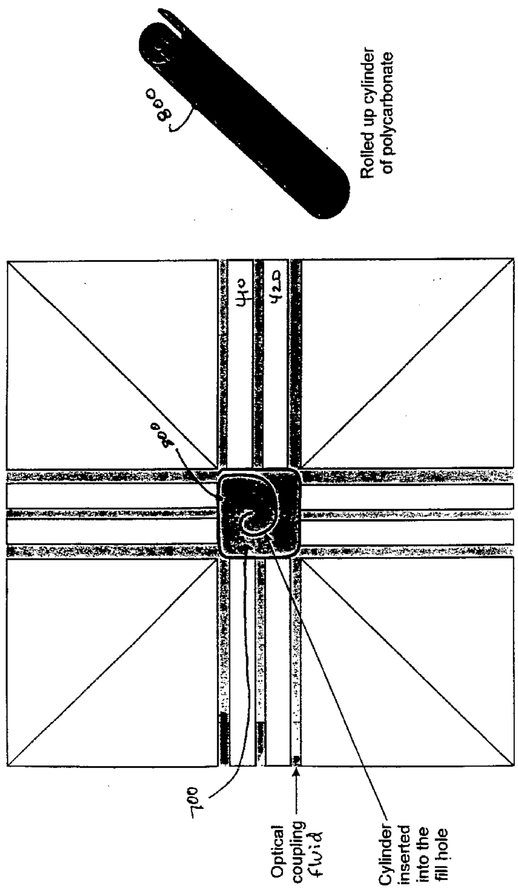

800
Rolled up cylinder
of polycarbonate
800
410
420
700
Optical
coupling
fluid
Cylinder
inserted
into the
fill hole

Fig. 9

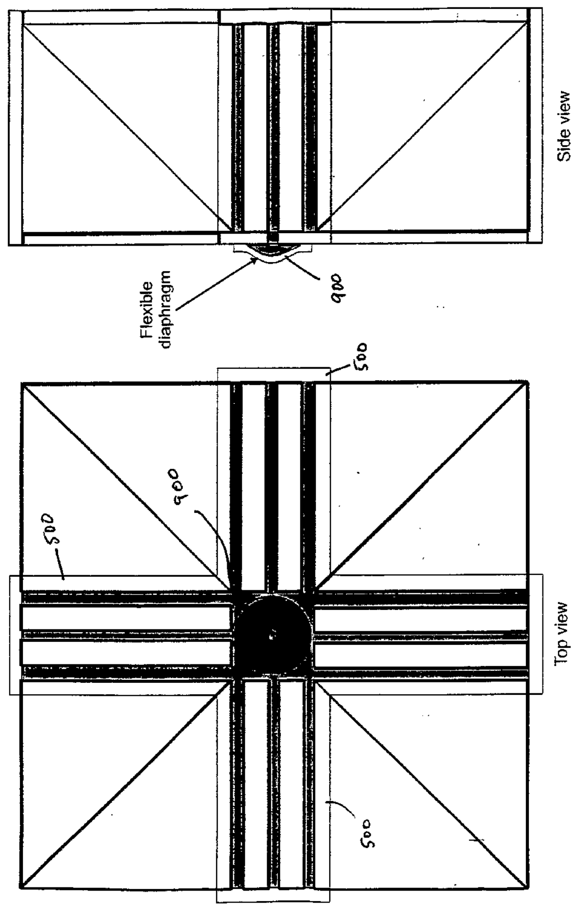


Fig. 10

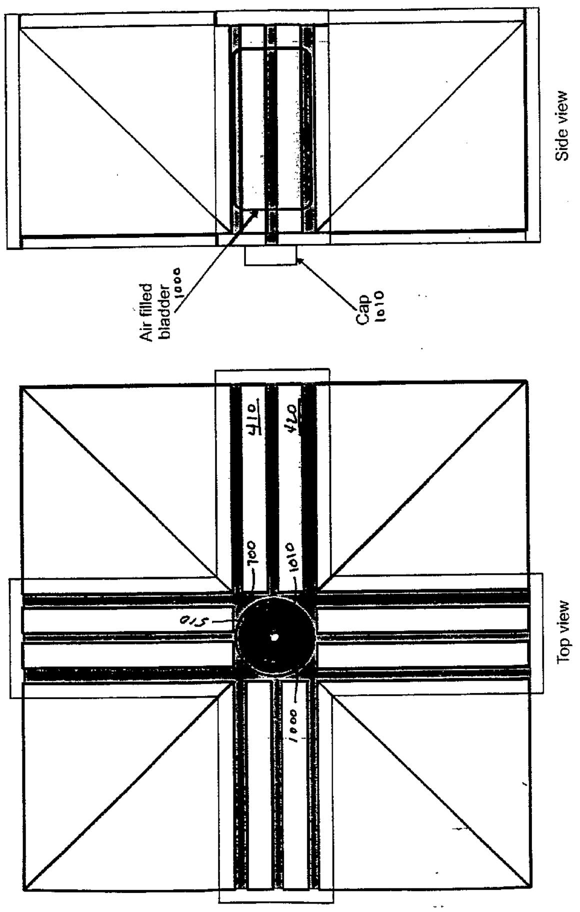

Side view
Air filled bladder 1000
Cap 1010
Top view
410
420
700
1010
510
1000

Fig. 11

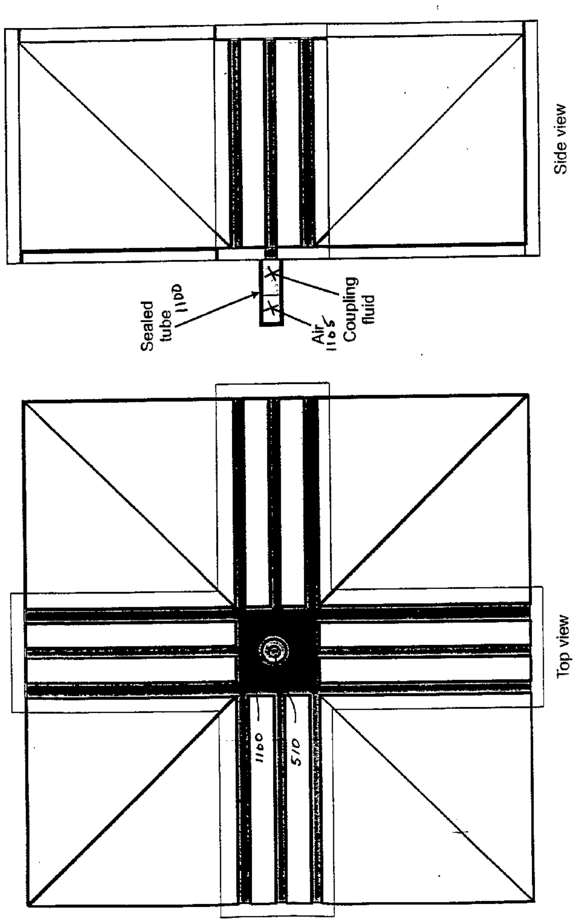

Side view
Sealed tube 1100
Air 1105
Coupling fluid
1100
510
Top view

Fig. 12

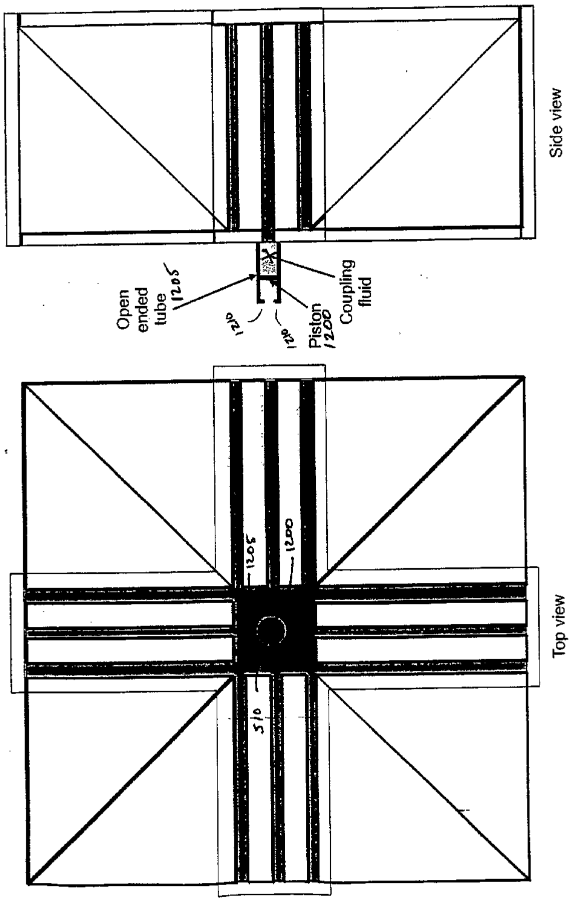
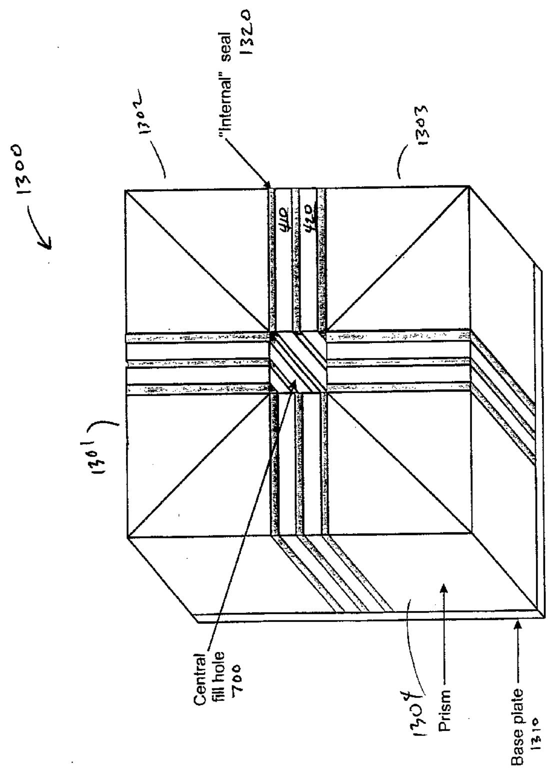
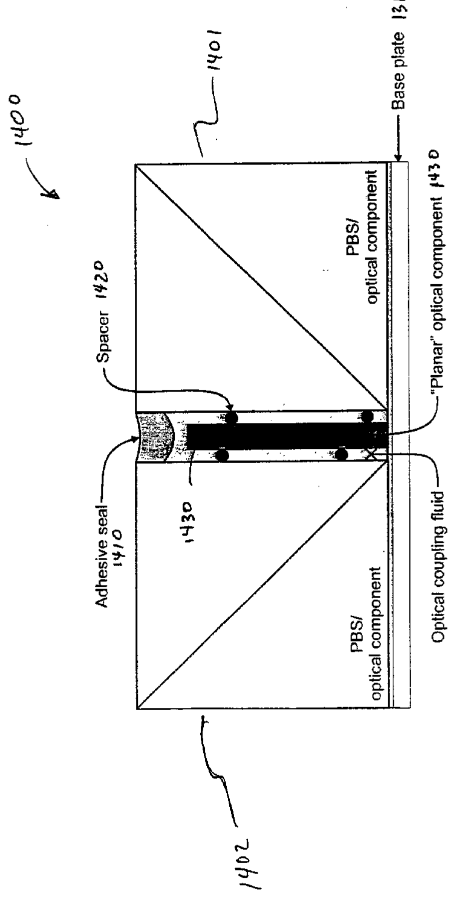

Side view
Open ended tube 1205
Piston 1200
Coupling fluid
1210
1205
1200
510
Top view

Fig. 13



1300
1301
1302
1303
"Internal" seal
1320
410
420
Central
fill hole
700
1304
Prism
Base plate
1310

Fig. 14


1400
1401
1402
Spacer 1420
Adhesive seal 1410
1430
PBS/ optical component
PBS/ optical component
Base plate 1310
"Planar" optical component 1430
Optical coupling fluid

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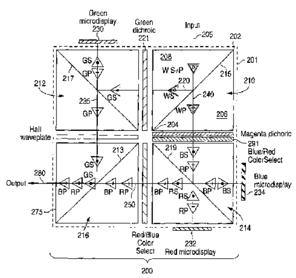
(54) Title: METHOD AND APPARATUS FOR CONFIGURATION AND ASSEMBLY OF A VIDEO PROJECTION LIGHT MANAGEMENT SYSTEM



(57) Abstract: A pathlength matched prism assembly (201) is contructed from Polarizing Beam Splitter optical components (210, 212, 214, 216) having varying degrees of precision by arranging them in pathlength matched positions and fixing them to a baseplate or frame. Gaps between the optical components are sealed by the frame or adhesive sealant. Planar optical elements (221, 291) are inserted between the optical components and space between the optical components and elements is filled with an optical coupling fluid having an index of refraction that closely matches the index of refraction of both components and elements. An expansion compensation device (550) is attached to the prism assembly to compensate for expansion and contraction of the optical coupling fluid. The prism assembly is best suited for use in HDTV and High Definition video projectors.

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METHOD AND APPARATUS FOR CONFIGURATION AND ASSEMBLY OF A VIDEO PROJECTION LIGHT MANAGEMENT SYSTEM

BACKGROUND OF THE INVENTION

Field of Invention

The invention relates to Light Management Systems (LMSs). The invention is more particularly related to improvements to LMS and their applications to reflective microdisplay based video projectors.

Discussion of Background

Light Management Systems (LMSs) are utilized in optical devices, particularly projection video devices and generally comprises a light source, condenser, kernel, projection lens, and a display screen, and related electronics. The function of the components of a video projector 100 is explained with reference to Fig. 1. As shown, white light 110 is generated by a light source 105. The light is collected, homogenized and formed into the proper shape by a condenser 115. UV and IR components are eliminated by filters (e.g., hot/cold mirrors 116/117). The white light 110 then enters a prism assembly 150 where it is polarized and broken into red, green and blue polarized light beams. A set of reflective microdisplays 152A, 152B, and 152C are provided and positioned to correspond to each of the polarized light beams (the prism assembly 150 with the attached microdisplays is called a kernel). The beams then follow different paths within the prism assembly 150 such that each beam is directed to a specific reflective microdisplay. The microdisplay that interacts with (reflects) the green beam displays the green content of a full color video image. The reflected green beam then contains the green content of the full color video image. Similarly for the blue and red microdisplays. On a pixel by pixel basis, the microdisplays modulate and then reflect the colored light beams. The prism assembly 150 then recombines the modulated beams into a modulated white light beam 160 that contains the full color video image. The resultant modulated white light beam 160 then exits the prism assembly 150 and enters a projection lens 165. Finally, the image-containing beam (white light beam 160 has been modulated and now contains the full color image) is projected onto a screen 170.

Commercially available prism assemblies include:

•Digital Reflection's Star Prism

•Philip's Trichroic Prism

•IBM's X Prism with 3 PBS

•S-Vision/Aurora System' Off-Axis Prism

•Digital Reflection's MG Prism

•ColorLink's ColorQuad Prism

•Unaxis' ColorCorner Prism

In the prism assembly, pathlengths are precisely matched. That is, the optical distance [] from each of the three microdisplays to an exit face (or output face) 155 of the prism assembly is essentially identical. This allows the microdisplays to be simultaneously in focus at the projection lens. In most currently available prism assemblies, the configuration of the prism assembly consists of precisely formed optical components that have been bonded together. The specific construction techniques by which this is accomplished provides differing advantages and disadvantages.

In some prism assembly configurations, an air gap is introduced between the microdisplays and a face on the prism assembly where the microdisplays are mounted. The air gap is a legitimate approach to accomplish pathlength matching, but has substantial disadvantages. For example, anti-reflection (AR) coatings are needed on the outer surfaces of the microdisplays and the prism assembly faces. The three microdisplays are aligned with respect to each other along all 6 axes of the microdisplay (x, y, z, roll, pitch, and yaw). Alignment is generally performed using mechanical positioners. Once alignment has been accomplished, the problem of maintaining the required precise alignment during the mechanical shock of appliance transport and during the thermal expansion/contraction that occurs while the video projector is in use still remains. In addition, the AR surfaces are exposed to dust, moisture and other atmospheric contaminates that may cause them to degrade. All of these factors reduce video projector performance.

In other prism assembly configurations the microdisplays are bonded to the faces of the prism assembly. Pathlength matching is accomplished by making the prism assembly have "perfect" (very precise) dimensions. Technologies currently being considered for producing these "perfect" dimensions include:

1. Tight Tolerance Component Fabrication

Source components may be fabricated to an extremely tight tolerance. However, such components are not currently available in high volume from vendors within the optics industry. When available, they will be very expensive.

2. Sort Components By Size

Measuring each component in an inventory and matching similarly sized components. The matched components are then used to construct a prism assembly. However, this requires an increased inventory of components from which to select matched sets of components.

3. Utilize Automated Assembly Equipment

The equipment measures the dimensions of each optical component and then actively adjusts their position during the assembly process. Such equipment must be custom designed and is expected to be quite expensive and inflexible.

In all three cases, extremely tight tolerances must be applied to the process used to assemble the optical components into the prism assembly. In all three cases, the outside dimensions of the resulting prism assembly, although having matched pathlengths, can still fall within a wide range. This requires that provisions be made within the video projector to mechanically adjust the position of the prism assembly with respect to the projection lens. Although bonding the microdisplays makes fabrication of the prism assembly more difficult, it has the advantage of eliminating the possibility of eventual misalignment of the microdisplays. In addition, the monolithic construction eliminates exposed surfaces and possible modes of degradation.

The prism assembly configurations each include several different types of plastic and/or glass materials. These disparate materials are bonded together. However, a difficulty arises because each material will have a different coefficient of thermal expansion. Since the prism assembly and its components will inevitably heat and cool during operation, the resulting expansion/contraction of the materials will generate stress (in fact, the process of assembly itself can build mechanical stresses into the prism assembly). Mechanical stress generates optical birefringence. Birefringence effects the polarization of the light beams traveling through the prism assembly and can be visualized on the screen as an undesirable artifact. It is, therefore, important to minimize the occurrence of stress within the prism assembly. One approach to minimize stress is to utilize glass that, in addition to meeting a long list of optical requirements, also has the lowest possible coefficient of stress induced birefringence. An example of one such glass is Schott's SF-57. The use of such a glass improves the situation but does not eliminate the problem.

Based on the considerations discussed above, it should be understood that there are many benefits to mounting the microdisplays directly onto the faces of the prism assembly. However, other various difficulties arise, including the expense of accomplishing the matching of the pathlengths and preparing microdisplays suitable for direct mounting. Furthermore, manufacturers of LMSs have had difficulties with attempts to implement such approaches in high volume manufacturing of any prism assembly configurations. The invention disclosed in this document consists of a prism assembly and construction techniques that can be applied to the construction of most prism assembly configurations (including all of those listed above). It enables inexpensive, high volume manufacturing of pathlength matched prism assemblies allowing the benefits of subsequent attachment of the microdisplays directly onto the faces of the prism assembly.

SUMMARY OF THE INVENTION

The present inventors have realized the need for cost effective pathlength matching and manufacturing techniques of Light Management Systems (LMSs) and particularly the construction of prism assemblies and microdisplay mounting on the prism assembly. The present invention describes a new approach to configuring the prism assembly, one that minimizes the undesirable optical consequences of mechanical stresses that arise within the prism assembly as a result of known construction techniques. The invention includes an inexpensive arrangement and method of constructing a pathlength matched prism assembly. The arrangement and method utilize less expensive, readily available optical components. Optically, the prism assemblies produced by this method are essentially identical and, therefore, can be used in a video projector with little need for mechanical adjustment. The invention can be applied to a wide range of prism assembly configurations and does not compromise other desirable mechanical or optical aspects of prism assembly performance.

In one embodiment, the present invention provides a prism assembly, comprising, a set of optical components arranged in pathlength matched positions, optical coupling fluid in contact with and between each of the optical components, and a frame affixed to each optical component and arranged so as to prevent optical coupling fluid leakage from between the optical components.

In another embodiment the present invention provides a prism assembly comprising, at least two optical components having imprecise dimensions configured to at least one of polarize, beam split, beam reflection and beam combine, said optical components fixed in a position such that pathlengths of beams directed through various paths in the prism assembly and to a focal point are matched, and an optical coupling fluid arranged in said pathlengths so as to contact at least two of the optical components.

In yet another embodiment, the present invention provides a prism assembly, comprising, a set of optical components, a baseplate attached to at least one of the optical components, a seal affixed to at least two of the optical components, and an optical coupling fluid disposed between the sealed optical components.

The present invention also includes a method of constructing a prism assembly, comprising the steps of, fixing a set of optical components to a baseplate, sealing spaces between the optical components, and filling spaces between the optical components with an optical coupling fluid. Various other methods and configurations will become apparent upon a detailed review of the disclosure and drawings as discussed below.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Fig. 1 is a drawing of a Light Management System (LMS) video projector;

Fig. 2 is a drawing of a simplified example kernel illustrating lightpaths and components of one possible configuration of a prism assembly in which the present invention is applied;

Fig. 3 is drawing illustrating a construction technique of an LMS prism assembly according to an embodiment of the present invention;

Fig. 4 is a drawing of liquid coupling of components in an LMS prism assembly according to an embodiment of the present invention;

Fig. 5 is a drawing of top and side views of a frame that holds components of an LMS prism assembly according to an embodiment of the present invention;

Fig. 6 is a drawing of spacers and liquid coupling of components of an LMS prism assembly according to an embodiment of the present invention;

Fig. 7 is a drawing illustrating a coupling fluid filling method according to an embodiment of the present invention;

Fig. 8 is a drawing of an example mechanism utilized to hold prism assembly components according to an embodiment of the present invention;

Fig. 9 is a drawing of a prism assembly equipped with a diaphragm 900 according to an embodiment of the present invention;

Fig. 10 is a drawing of an embodiment of a bladder equipped prism assembly according to an embodiment of the present invention;

Fig. 11 is a drawing of an embodiment of a sealed tube assembly according to an embodiment of the present invention;

Fig. 12 is a drawing of an open air piston arrangement according to an embodiment of the present invention;

Fig. 13 is a drawing of an internally sealed prism assembly according to an embodiment of the present invention; and

Fig. 14 is a close-up of an internal seal of an internally sealed prism assembly according to an embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring again to the drawings, wherein like reference numerals designate identical or corresponding parts, and more particularly to Fig. 2 thereof, there is illustrated a Light Management System (LMS) kernel 200 illustrating lightpaths and components of one possible configuration of a prism assembly in which the present invention is applied. Path length matching and other features are provided based on the present invention. The kernel 200 includes a prism assembly 201, attached microdisplays ("Green" microdisplay 230, "Red" microdisplay 232, and "Blue" microdisplay 234 – the colors are in quotations because the color identifies the content of an image to be displayed, or the light being manipulated, by the individual microdisplay). The kernel is a fundamental component of a video projection system.

The prism assembly 201 comprises a set of optical components, films, and matching elements making a single prism assembly unit. A white light 205 is directed at a Polarizing Beam Splitter (PBS) 210. A polarizing beam splitter thin film 215 perpendicularly polarizes and splits the white light into two beams of polarized light 220 and 240. The lightpaths through the prism assembly are each labeled to indicate the color and polarization of each light path. For example, incoming white light 205 is labeled W S + P (meaning White S and P polarized); light beam 220 is initially labeled WS (meaning white, s-polarized). The s-polarized white light 220 passes through a green dichroic filter 221 (passing green light, making beam 220 a green s-polarized beam (and labeled GS)), and enters a second Beam Splitter 212. A polarizing beam splitter thin film 217 reflects the s-polarized green light to "green" microdisplay 230.

The green microdisplay 230 manipulates the polarized green light according to green content of an image to be displayed. The "green" microdisplay modulates the polarization of the green light on a pixel-by-pixel basis. For example, a no green content pixel of the image to be displayed will be left unaltered, a strong green content pixel of the image to be displayed will have its polarization rotated 90°, and other pixels having varying levels of green content will have their polarization rotated in varying amounts in proportion to the amount of green content. The microdisplay also reflects (reflection or other polarization effects on the light are accounted for by the polarization manipulation of the microdisplay) the green light (now modulated) back toward the polarizing beam splitter thin film 217.

The polarizing beam splitter thin film 217 then reflects some portions and passes other portions of the green light. The amount of light reflected versus passing is based on the amount of modulation performed on the reflected green light. Light with the same polarization as was reflected into the green microdisplay is again reflected. Light that is oppositely polarized (or at least different from a polarization sensitivity of the polarizing beam splitter thin film 217) is passed. Amounts of green light less than the full amount of original green light and more than 0 depend on the amount of modulation (modulation in this example is the amount of polarization rotation).

Beam 235 represents the modulated green light that passes back through the polarizing beam splitter thin film 217 (e.g. green light sufficiently modulated to pass through the polarizing beam splitter thin film 217). Beam 235 enters final Beam Splitter 216 and is reflected off polarizing beam splitter thin film 213. Each of the red and blue components are similarly modulated and passed or reflected from corresponding polarization sensitive materials, to produce beam 250. After reflecting off polarizing beam splitter thin film 213, the modulated green light beam 235 is combined with the red and blue components of beam 250 and then exits the prism assembly through output face 275 as white light 280 containing the image to be displayed.

PBSs 210, 212, 214, and 216 are constructed similarly. In this configuration, each PBS contains 2 optical components (e.g., prisms 208 and 206) and a polarizing beam splitter thin film (e.g. 215). The polarizing beam splitter thin film is, for example, a coating that reflects s-polarized light and passes p-polarized light. Optical elements (e.g., retarders, rotators, etc) are utilized to change the polarization so that desired light beams are either reflected or passed by the polarizing beam splitter thin film so that subsequent polarizing beam splitter thin films may pass or reflect the desired light beams depending on the configuration of optical components and the desired path of each light beam (Fig. 2 is one example configuration and desired paths). For example, when PBS 210 splits the incoming white light into 2 beams, the second beam 240 passes through a wavelength specific retarder (Blue/Red ColorSelect 291) so that PBS 214 can also split beam 240 into component beams directed to each of the red microdisplay 232 and blue microdisplay 234 (without the retarder, the blue component of the white light in beam 240 would remain p-polarized and PBS 214 would then pass the blue light to the red microdisplay 232 instead of reflecting it to the blue microdisplay 234).

The configuration of Fig. 2 illustrates a prism assembly made from 4 similarly constructed PBSs, an advantage over systems utilizing optical components performing a variety of functions (and hence, a variety of differently configured optical components) because the similarly constructed PBSs reduce the number of parts and different functionality of components in a particular optical design. Hence, a corresponding production line benefits from economies of scale, reduced inventory, etc. However, it can also be seen that many different combinations of optical elements can be utilized to make the various beams properly reflect or pass and then re-combine into final light beam 280. Furthermore, the prism assemblies using optical components having a variety of different functions can be constructed. And, as noted above, prism assemblies of all these varieties (different sizes, different shapes, different configurations, etc.) may be constructed using the techniques and processes discussed herein.

Optical components are combined to create the beam splitters. For example, individual prisms 206 and 208 are optical components that are combined to produce the Polarizing Beam Splitter (PBS) 210. Before manufacture of the prism assembly, the beam splitting optical components are built. Prism assembly 201 illustrates four beam splitting optical components, polarizing beam splitters (PBSs) 210, 212, 214, and 216. Each of the polarizing beam splitters (hereinafter referred to as PBSs) contains a polarizing beam splitter thin film (e.g., 215, 217, 219, and 213). Preferably, the polarizing beam splitter thin films are at the diagonal of the beam splitters and extend through the corner as defined by the outside surfaces of the PBS. For example, the polarizing beam splitter thin film 215 extends along the diagonal of 206 and 208 through corners 202 and 204 of the PBS 210. The PBSs may be constructed so that the polarizing beam splitter thin film is on a plane of the diagonal and need not extend through the corners, particularly if light does not pass through the entire range of the diagonal.

The assembly of such PBS is accomplished by the use of optical pathlength matching. Referring to PBS 210, it can be noted that the two optical components (prisms) 206 and 208 need not be exactly the same size (and, consequently, the outside dimensions of the PBS need not meet any specific dimensional requirement). Since there are no specific dimensional requirements for the PBS, optical components with a "loose" mechanical tolerance may be utilized. Such optical components (and prisms used to construct those components) can be produced at modest cost and in high volume by existing vendors of optical components.

The optical components are assembled from the "outside in". As shown in Fig. 3, the two outside surfaces of each of the four PBSs in the prism assembly 201 are accurately held in position by precision alignment corners 300 of an assembly tool 310. For example, outside surfaces of PBS 210 are held in a fixed position determined by alignment corner 300A.

Assembly tool includes an assembly tool base plate 315 to which the precision alignment corners 300 are fixed. Construction of the alignment corners 300A, 300B, 300C, and 300D can be performed using mechanical tooling. The alignment corners are constructed to a tolerance and positioned on the assembly tool base plate such that they precisely fix the outside dimensions of each PBS. Each alignment corner includes a device for securing the PBS in position during assembly. For example, PBS 210 is held tight in alignment corner 300A via vacuum holders 330 and 335. The vacuum holders are connected to vacuum pump 330 via vacuum tube 325. In one embodiment, there is a single vacuum holder in the corner of the alignment corner.

The alignment corners provide the precise dimensional accuracy required to achieve pathlength matching and is accomplished by mechanical tooling rather than expensive tightly toleranced optical components. However, pathlength matching alone does not produce an acceptable prism assembly. Although pathlength matched, because the optical components are of varying non-precise tolerances (different sizes), the PBS do not fit precisely together (e.g., intersection of PBS 210 and 214, and any dichroics or filters placed therebetween, do not fit exactly) and an air gap is introduced between the internal optical surfaces of the PBSs. The air gap itself introduces other problems including refraction and other optical variations that need to be reduced or eliminated.

The present invention reduces the undesirable effects from the imprecisely fit PBSs by coupling the PBSs with a liquid. In one embodiment, all internal optical surfaces of the prism assembly are coupled using a liquid. Fig. 4 is a drawing of liquid coupling of components of an optical assembly according to an embodiment of the present invention. Between adjacent PBSs is a joint that is filled with liquid. The thickness of the liquid filled joints is varied based on variations in size of the individual PBSs (or other optical components utilized in other prism assembly configurations) to maintain the desired exterior dimensions of the prism assembly (e.g., to maintain desired matched pathlengths within the prism assembly). For example, Liquid filled joint J1, the joint between PBS 212 and PBS 216 comprises liquid between the PBSs, the entire joint comprising the liquid coupling fluid 400 in spaces t1, t2, and t3, and dichroics and other optical elements placed between the PBS (e.g., optical element 410 and 420 placed between the PBS). The other optical elements may be, for example, any combination of dichroics or other filters. Accommodation in the liquid coupling fluid will prevent stress from building up in the components.

In one embodiment, a frame, glued to the external surfaces of the prism assembly, is used to contain the liquid and hold the components in place. Fig. 5 is a drawing of top and side views of a frame 500 that holds components of an LMS prism assembly according to an embodiment of the present invention. The frame 500, which can be made of one or several pieces (note that there are not any optical requirements on the frame material), is placed over each of the joints between the PBSs. In this embodiment, the frame 500 comprises 2 side components 500A and 500 C, and 4 edge components 500B. Each side component is a plus sign (+) shaped glass, plastic, acrylic, etc., or other material, each appendage of the plus sign covering a joint, and the middle of the plus sign covering a conjunction of all 4 joints. The edge components 500B cover the edge of each of one of the joints. The top side component 500A includes a fill hole 510 to which fluid may be applied and/or added as needed. A cap (not shown) is used to cap off the fill hole to prevent spillage of the fluid. An air bubble 550 is provided to compensate for liquid expansion/contraction and prevent stress build up on the optical components. The frame 500 is illustrated as a plus sign shape, but may be completely rectangular or any other shape, so long as it covers each joint sufficiently. Glue or other adhesive applied to the frame creates a seal between the frame and the PBSs so as to fully contain the coupling fluid. The glue or other adhesive also fixes the position of the PBSs to the frame to assure nonmovement of the PBSs with respect to each other (maintaining the monolithic nature of the LMS).

Using the adhesive between the frame and PBSs to fix the matched pathlengths is performed by determining the matched pathlength positions of the prism assembly components (e.g., using a tool having corner pieces or other positioning devices to assure the correct optical pathlengths), and then gluing the components (e.g., PBSs) to one or more parts of the frame at those matched pathlength positions. Additional optical elements are then positioned in the joints (e.g., optical elements 410 and 420), the joints are then at least partly filled with optical coupling fluid (liquid coupling fluid), the joints are then capped with a top frame piece, and then the coupling fluid is topped off (except for the air bubble or other expansion air space), and then the fill hole is capped.

The present invention includes various methods and devices to fill the prism assembly with the coupling liquid. For example, Fig. 7 is a drawing illustrating a coupling fluid filling device and method according to an embodiment of the present invention. The coupling liquid is injected into a central fill hole 700 utilizing a syringe filled with coupling fluid. The central fill hole 700 is a center area of the prism assembly, and generally has no optical components therein. However, it is possible that one or more of the optical components may be positioned at least part way into the central fill hole. In one embodiment, the prism assembly is at least partly filled prior to affixing a top portion of the frame onto the prism assembly. If the top portion of the frame is not attached, the coupling fluid may also be applied in an area other than the central fill hole, but filling at the central fill hole is preferred. Also preferable, is injecting the coupling fluid at the bottom of the central fill hole. Capillary action between the optical elements and PBSs in both vertical and horizontal directions will assist the filling process. In other embodiments, the same process occurs with the top portion of the frame in place, in which case the syringe is inserted through the fill hole 510 (cap removed) to the bottom of the central fill hole 700, and the prism assembly is filled with coupling fluid. Other devices including tubes, pumps, or other pouring mechanisms may be used to place the fluid in the central fill hole.

Recognize that, if the components within the prism assembly were to directly touch (e.g., optical element 410 directly touching either optical element 420 or PBS 212), the result could be a visible artifact in an image projected by the prism assembly. The solution to this problem is to assure that a thin layer of liquid exists between the components and or elements of the optical assembly. Many different methods and/or devices may be implemented to assure that a layer of liquid exists between components. For example, the optical elements may be physically separated during filling of the coupling fluid, spacers may be affixed to portions of the frame to separate the elements and PBSs. In one embodiment, spacers are applied between the optical surfaces. Fig. 6 is a drawing of spacers (spacer balls 600) and liquid coupling of components of an LMS prism assembly according to an embodiment of the present invention. The spacers can be glass rods or balls with diameter on the order of thousandths of an inch. The index of refraction of the liquid coupling fluid is chosen to match that of the spacers thus rendering them invisible.

The present invention includes various methods and devices for application of the spacers. In one set of embodiments, the spacers are applied directly to the optical surfaces of the PBSs and/or optical elements. In one embodiment, the spacers are sprayed onto the optical surfaces. Spraying spacers onto optical surfaces may be performed using liquid crystal display manufacturing techniques and machinery. Either wet or dry spacer application may be utilized. In other embodiments, the spacers are suspended in the liquid coupling fluid at least during manufacture. After manufacture of the prism assembly, suspended spaces remain lodged between the optical surfaces and/or settle to a bottom portion of the prism assembly out of the viewing area.

The liquid coupling fluid is an optical coupling fluid selected to have an index of refraction that matches (or closely matches) the index of refraction of the PBSs and any optical elements spaced within the fluid. The index of refraction changes depending on wavelength, and is different for each of the components and elements in the prism assembly. Typical values are 1.52 for plastic elements, and 1.71 for glass components. The optical coupling fluid generally preferred to have an index of refraction in the 1.50-1.85 range. A 1.6 index of refraction optical coupling fluid has worked well in experiments carried out by the inventors. Similarly, in the embodiments using spacers, the optical coupling fluid is chosen to have an index of refraction preferably matching each of the PBSs, optical elements, and spacers as closely as possible. Matching the index of refraction can be done by splitting the difference between the index of refraction of the optical components and elements. Another method would be to perform an impedance matching type of arithmetic (e.g., taking the square root of the sum of the squares of the index of refraction of each optical component/element). However, the present inventors note that selection of any index of refraction between the high and low index of refraction of the optical components and elements provides better matching than any other embodiments of the pathlength matched prism assembly, including the gel, cured epoxy, and air filled embodiments discussed elsewhere herein. The chosen index of refraction of the coupling fluid may also be weighted toward matching component interfaces that occur more frequently in the prism assembly. In one embodiment, the index of refraction of the coupling fluid matches the index of refraction of the spacers.

Important properties for the coupling fluid are toxicity, flammability, yellowing propensity, chemical properties, and cost. Toxicity and flammability are safety considerations, the product is preferably non-toxic and non-flammable. Also, the optical coupling fluid, to be practical, needs to be resistant to yellowing, particularly under intense light and heat conditions. The optical coupling fluid has to have chemical properties that do not react with other optical elements, components, and parts of the prism assembly. And, to be commercially practical, the optical coupling fluid needs to be relatively inexpensive and readily available. In one embodiment, the optical coupling fluid is, for example, mineral oil. Many different types and properties of optical coupling fluid are commercially available (e.g., Cargille Corp makes many different types of index matching fluid).

In one embodiment, the optical coupling fluid is a UV curing adhesive, which, when cured, makes a solid prism assembly, the cured adhesive coupling the optical elements/components without fluids. However, the liquid filled embodiments have better index of refraction matching than commercially practical UV curing adhesive, so the liquid filled embodiments are preferred. In another embodiment, optical coupling is performed by inserting an optical coupling gel between the various components/elements of the prism assembly. NYE corporation makes one such gel (matching gel). In yet another embodiment, the coupling material is air, or another gas is utilized as a coupler between the optical components and elements. In the air-filled embodiment, anti-reflection coating are places on the surfaces of the optical elements and components to eliminate or reduce reflections.

Note that variations of the assembly techniques described herein can be applied to any of the prism assembly configurations discussed in this document.

There are several other advantages offered by the configuration and manufacturing method described above. These include the following:

Several prism assembly configurations include polarization-rotating component(s) (rotators) (e.g., rotating beam 235 after being passed by polarizing beam splitter thin film 217 so it is then reflected by polarizing beam splitter thin film 213). Rotators are generally constructed of layers of polycarbonate plastic bonded together. In prior systems, the adhesive needs to be able to bond the polycarbonate plastic of the rotator to the glass of the prism assembly components. The common solution to this problem is to purchase the polarizing rotator from the vendor in the form of a "sandwich". In "sandwich" form, the rotator has been bonded between two cover glasses. The cover glasses make it easier for the prism assembly manufacturer to bond the rotator into the prism assembly (e.g., bonding between surfaces of adjacent cover glasses). However, compared to the polycarbonate rotator itself, the sandwich may be available only in limited supply and is more expensive. In contrast, in the present invention, The liquid coupling method allows the direct use of the inexpensive, readily available polycarbonate component. Since with liquid coupling the polycarbonate is not bonded with adhesive, this class of problems is eliminated.

The precise outside dimensions of the prism assembly obtained using the new manufacturing method not only allow direct mounting of the microdisplays onto the prism assembly, but also allows for the use of precision (or fixed) mounting points for mounting the completed kernel (prism assembly with microdisplays attached) into the device in which it is to be used (e.g., light engine). The use of precision or fixed mounting points reduces or eliminates the need for a physical adjustment mechanism and procedure when mounting the kernel into the light engine.

Conventional prism assemblies generally utilize a series of glue cure steps. As the prism assembly grows in size and complexity, it becomes progressively more difficult to cure the adhesives due to the absorption of light by the glass and/or the optical properties of the components. Liquid coupling as provided by the present invention eliminates this problem and can greatly reduce the time required for prism assembly.

The present invention includes a device and method to hold the optical elements (e.g., optical elements 410 and 420) in place. The optical elements are also generally referred to as flat components because they are generally rectangular in shape and flat (having a thin width). However, the present invention may be practiced using different shapes and widths of the optical components.

One concern at any time, including manufacture, shipping, storage, and/or during actual use is the potential movement of optical components in the coupling fluid. Movement towards the central fill hole 700 could potentially leave the moved component (or parts of the moved component) out of the optical path. The present invention provides for placing a spacer device in the central fill hole 700 to hold the flat components in a stable general location. Fig. 8 is a drawing of an example spacer device 800 utilized to hold optical components according to an embodiment of the present invention. In the illustrated embodiment, the spacer device 800 is a sheet of polycarbonate rolled into a tight cylinder. The spacer device 800 is inserted into the central fill hole 700. Once in place, the cylinder will "unroll" and press on the components so as to keep them out of the central hole.

As previously discussed an air bubble may be left inside the prism assembly to account for expansion of the various components. One problem with expansion of the components is that the components expand at different rates. As the optical coupling fluid expands, so does the optical components of the prism assembly. however, the expansion of the liquid and optical components is at different rates (differential expansion). In most cases, the optical coupling fluid expands at a higher rate than the optical components. Without the air bubble, an amount of stress is applied against the optical components by the expanding fluid. Without the air bubble, this stress can cause an undesirable amount of stress induced birefringence effecting the various light beams passing through the optical components of the prism assembly as the liquid coupling fluid expand.

Referring back to Fig. 5, an air bubble 550 is illustrated. The air bubble 550 is permanently maintained within the prism assembly once the fill hole 510 is capped. In Fig. 5, the "frame" elements (500A, 500B, and 500C) on the outside of the prism assembly serve both to contain the liquid and to hold the prism assembly components rigidly in space.

In the example embodiment of Fig. 5, the volume within the prism assembly surrounded by frame 500 is occupied by glass of the prism assembly components (e.g., PBSs), optical elements, and the optical coupling liquid. As the temperature of the prism assembly rises (as it will during operation) the linear and volume dimensions of all components increase. However, at least partly due to the fact that the coefficient of thermal volumetric expansion of the optical coupling liquid is considerably higher than that of the glass and other materials, when the temperature rises, the volume of the liquid expands faster that that of the glass "container" (optical components and frame bounding the liquid). In addition to the undesirable optical effects, excessive stress caused by this differential expansion could potentially cause the bonded components to separate. The air bubble 550 is one way to accommodate the effects of differential expansion and avoid the build up of stress.

Fig. 9 is a drawing of a prism assembly equipped with a diaphragm 900 according to an embodiment of the present invention. The diaphragm 900 is constructed of a flexible material such as rubber, plastic, or another material with sufficient strength and flexibility to accommodate the expanding fluid and thereby relieve stress. The diaphragm 900 flexes as the volume of liquid increases or decreases. Preferably, the diaphragm 900 is circular and affixed over the fill hole 510 using an adhesive. However, other shapes and attachment mechanisms may be utilized (e.g., the flexible material fitted under a ring clipped to the frame around the fill hole).

Fig. 10 is a drawing of an air bladder 1000 equipped prism assembly according to an embodiment of the present invention. In one embodiment, the frame 500 is capped (e.g., cap 1010), and a bladder is inserted inside the optical assembly. The bladder expands and contracts as the volume of liquid decreases and increases.

The air filled bladder 1000 is inserted into the fill channel (central fill hole 700). The volume of the bladder can increase or decrease to accommodate volumetric changes in the coupling liquid. In alternative embodiments, the bladder may be filled with any suitably compressible material (e.g., gas, liquid, solid, or combination thereof). The bladder 1000 can also serve to assist in holding those components in place that are not glued to the frame (e.g., the "flat" components (e.g., 410, 420)located between the polarized beamsplitting cubes). When configured to assist in holding the "flat" components in place, spacers such as polycarbonate roll 800 are not needed.

Fig. 11 is a drawing of an embodiment of a sealed tube 1100 assembly according to an embodiment of the present invention. A sealed tube 1100 is attached to the fill hole 510. A portion of the sealed tube 1100 contains an air bubble 1105. The air bubble 1105 will enlarge or shrink to accommodate expansion or contraction of the liquid within the prism assembly. In this approach, similar to the air bubble only approach discussed above, it is important to understand the orientation of the prism assembly in the light engine application. The reason being that the air bubble 1100 will migrate to the highest point within the prism assembly. It is therefore necessary to design the system such that the end of the tube is a high point. The tube may be configured with an elbow or other structure to direct the air bubble to an appropriate location. In the case of the air bubble only approach, it is therefore important that the high point of the prism assembly (high point of fluid in the prism assembly) is not at a point in of the optical paths of the prism assembly.

Fig. 12 is a drawing of an open air piston 1200 arrangement according to an embodiment of the present invention. An open ended tube 1205 is attached to the fill hole 510. A sliding piston 1200 fits snugly inside the open ended tube. As the optical coupling liquid expands with increasing temperature, the piston 1200 slides outward within the open ended tube. As the optical coupling liquid shrinks with decreasing temperature, surface tension (and/or pressure variance between the inside and the outside of the prism assembly) causes the piston to slide inward within the open ended tube 1205. In one embodiment, the open ended tube is longer than a predicted maximum expansion of the optical coupling fluid. In one alternative, stops 1210 are positioned inside the open ended tube to prevent the piston from reaching the open end of the tube 1205. In another alternative, the stops 1210 are electrodes connected to an emergency shut-off circuit, and the piston 1200 has a conductive material on its outer surface. When the piston contacts stops 1210, the light engine to which the prism assembly is installed is shut down at least until the prism assembly is sufficiently cooled to disengage piston 1200 from the stops 1210. As with all the embodiments listed herein, the open ended tube may be combined with one or more other embodiments (e.g., air bladder) to provide stress relief to compensate for the expanding and contracting optical coupling fluid.

Each of the above embodiments have an external frame (e.g., frame 500 – external to the optical components of the prism assembly) that seals the prism assembly and contains the optical coupling fluid (and include any necessary attachments for any of the stress relief features discussed above). The frame also provides structural strength to the prism assembly. However, the present inventors have also realized the need for a compact arrangement for sealing the optical coupling fluid. The compact arrange then allows for the prism assembly to be utilized in a wider variety of optical applications, including different LCoS based video projection systems.

Furthermore, any newly designed and/or previously existing light engine systems can be fitted with a fluid coupled prism assembly. In new designs, fitting the liquid coupled prism assembly may be performed by fitting mounts within the projection system to accommodate one or more liquid coupled prism assembly sizes. However, in the case of retrofit systems (fitting liquid filled prism assemblies to previously sold projection systems and/or fitting liquid coupled prism assemblies to new projection system of a previous design); physical accommodation of the liquid coupled prism assemblies may not be so easily accomplished. That is, the physical size and shape of a fluid coupled prism assembly may not allow it to directly fit into the position provided for a conventional prism assembly within an existing light engine. The modifications of the light engine required to accommodate a fluid coupled prism assembly may be difficult, expensive or, in an extreme case, not possible. Therefore, by providing a fluid coupled prism assembly that is sealed and provides structural strength and has external dimensions that are similar to that of an equivalent conventional prism assembly, that prism assembly could be used as a drop in replacement for a conventional prism assembly in any light engine design. The invention disclosed in this document is such a means.

For these reasons, the present inventors have also developed an internally sealed prism assembly that seals and provides structural integrity to a liquid filled prism assembly.

Fig. 13 is a drawing of an internally sealed prism assembly 1300 according to an embodiment of the present invention. The internally sealed prism assembly 1300 includes a baseplate 1310 and at least one internal seal 1320 between optical components of the prism assembly. Comparing this embodiment to the previous configurations, most features of the external frame are absent except the base plate 1310 (the base plate being a feature common to both the conventional and fluid coupled prism assembly configurations). The base plate 1310 provides a secure, firm surface for attaching the PBSs 1301-1304. As illustrated in Fig. 13, the internal seal is fitted between optical elements 410 and 420, between optical element 410 and PBS 1302, and between optical element 420 and PBS 1303.

The internal seal extends downward from the top of the optical elements/PBSs a short distance (e.g., 1 mm) to produce a seal that maintains the optical coupling fluid installed into the prism assembly. In one embodiment, the internal seal also overlaps the tops of the optical elements 410 and 420, such that the seal covers the exposed surfaces of the optical elements, but preferably does not extend beyond the outer surface of the PBSs. In depth, the seals seeps between the optical elements/PBSs to a prescribed sealing depth (e.g., 1 mm).

Fig. 14 is a close-up of an internal seal of an internally sealed prism assembly 1400 (part view) according to an embodiment of the present invention. In Fig. 14, 2 PBSs 4101 and 1402 have an internal seal 1410 between them. The internal seal may be described as a "picture frame" between the PBS elements. The adhesive does not extend beyond the outer surface of the prism assembly. Preferably, the internal seal is an adhesive agent that not only seals the prism assembly, preventing leakage of the optical coupling fluid, but may also provide additional rigidity to the entire structure. The adhesive may be, for example a 1 or 2 part epoxy or a UV cured adhesive that both hardens and seals.

Alternatively, the adhesive seal may be a pliant adhesive such as silicone based adhesives. However, flexing of the prism assembly can become an issue if non-hardened sealant is utilized. While the bottom plate of the frame provides enough rigidity that pliant adhesives may be acceptable in some applications, a top plate (on the side of the prism assembly opposite the base plate) in addition to the base plate adds enough rigidity that pliant adhesives are fully acceptable in most all applications.

Fig. 14 also illustrates an optical element ("Planar" optical component 1430) separated by spacers 1420. The optical element is shorter than a bottom height of the adhesive sealant. The optical element is representative and may in fact be several optical elements also separated from the PBSs and each other via additional spacers. The "planar" optical components 1410 are items such as dichroics, reflective polarizers and wavelength specific retarders contained between the PBSs and suspended in the optical coupling liquid. The planar components are spaced from the glass surfaces by use of spacer elements as discussed previously.

Penetration (the prescribed sealing depth) of the adhesive 1410 is confined to a region out of the optical path. The base plate 1310 provides the required rigidity to the prism assembly.

As explained above, the principle advantages of the disclosed liquid coupled prism assembly techniques and configurations include the ability to use less expensive, low tolerance glass components, and the ability to fabricate a prism assembly with "perfect" outside dimensions and in so doing, enabling the attachment of microdisplays directly to the prism assembly. In turn, the latter provides several advantages the foremost being that the resulting monolithic assembly will remain in a alignment under a wide range of conditions.

An alternative means by which these advantages can be obtained is to utilize the "build from the outside in" procedure described previously but, rather than filling the prism assembly with an optical coupling liquid, leaving the assembly empty therefore "filling" with air. However, in this approach, it will be necessary to coat all surfaces now exposed with an anti-reflection thin film (AR coatings) to suppress reflections. The expansion port is not required in this configuration. In some applications it may be possible to also omit the side rails of the frame (e.g., 500B) and possibly the top (500C).

In yet another alternative, the prism assembly is filled with an epoxy that cures. Preferably the cured epoxy has an index of refraction that closely matches the index of refraction of the PBSs and optical elements utilized. In still yet another embodiment, a gel substance may also be used to fill the joints between adjacent PBSs. Again, preferably, the gel has an index of refraction that approximates that of the other parts of the prism assembly. An example gel that could be utilized is manufactured by NYE Corporation.

In describing preferred embodiments of the present invention illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the present invention is not intended to be limited to the specific terminology so selected, and it is to be understood that each specific element includes all technical equivalents which operate in a similar manner. For example, when describing a spacer device constructed of rolled polycarbonate, any other equivalent device, such as a geometrically shaped (square, triangle, pentagon, hexagon, etc) or other shape roll of polycarbonate or any other material or any other device having an equivalent function or capability, whether or not listed herein, may be substituted therewith. Furthermore, the inventors recognize that newly developed technologies not now known may also be substituted for the described parts and still not depart from the scope of the present invention.

The present invention is mainly described in conjunction with a LMS that utilizes a microdisplay that operates by rotating polarization of individual pixels. However, based on the description provided herein, it should be understood that the present invention may be practiced in devices with other types of microdisplays (e.g., scattering, absorption, diffraction based microdisplays), or in optical devices constructed without microdisplays.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

WHAT IS CLAIMED IS:

1. A prism assembly, comprising:

a set of optical components arranged in pathlength matched positions; and

a frame affixed to each optical component and arranged so as to prevent optical coupling fluid leakage from between the optical components.

2. The prism assembly according to Claim 1, further comprising an optical coupling substance in contact with and between each of the optical components.

3. The prism assembly according to Claim 2, wherein said optical coupling substance is a liquid.

4. The prism assembly according to Claim 2, wherein said optical coupling substance is a gas mixture.

5. The prism assembly according to Claim 4, wherein said gas mixture is air.

6. The prism assembly according to Claim 5, wherein said optical components include at least one anti-reflection coating on a surface of the optical components.

7. The prism assembly according to Claim 2, wherein said optical coupling substance is a gas.

8. The prism assembly according to Claim 2, wherein said optical coupling substance is a gel.

9. The prism assembly according to Claim 2, wherein said optical coupling substance is a UV cured adhesive.

10. The prism assembly according to Claim 1, wherein said pathlength matched positions are physical pathlength matched.

11. The prism assembly according to Claim 1, wherein said optical components comprise at least one polarizing beam splitter.

12. The prism assembly according to Claim 1, further comprising a set of corner blocks configured to fix placement of outside surfaces of the optical components.

13. A prism assembly comprising:

at least two optical components having imprecise dimensions configured to at least one of polarize, beam split, beam reflection and beam combine, said optical components fixed in a position such that pathlengths of beams directed through various paths in the prism assembly to a focal point are matched; and

an optical coupling fluid arranged in said pathlengths so as to contact at least one of the optical components.

14. The prism assembly according to Claim 13, wherein the imprecise dimensions of the optical components are such that said pathlengths are not matched to a precision that if the optical components were fitted together, said pathlengths would not provide a focus to beams directed through the prism assembly and then recombined before a focal point.

15. A prism assembly, comprising:

a set of optical components;

a baseplate attached to at least one of the optical components;

a seal affixed to at least two of the optical components; and

an optical coupling fluid disposed between the sealed optical components.

16. The prism assembly according to Claim 15, wherein said seal comprises an adhesive connecting internal optical surfaces between adjacent sealed optical components.

17. The prism assembly according to Claim 16, further comprising a set of at least one planar optical components disposed between at least one of the adjacent sealed optical components.

18. The prism assembly according to Claim 17, further comprising spacers contained in the optical coupling fluid.

19. The prism assembly according to Claim 17, where at least one of the planar optical components divides the seal between the adjacent optical component.

20. The prism assembly according to Claim 15, wherein said set of optical components comprises 4 Polarizing Beam Splitter (PBS) components arranged in a rectangular shape;

said seal encloses the interior optical surfaces of the PBSs to form an optical coupling fluid tight container.

21. The prism assembly according to Claim 20, wherein the rectangular shape is a square.

22. The prism assembly according to Claim 20, wherein the rectangular shape comprises a pathlength matched optical paths through the prism assembly for 3 distinct light beams.

23. The prism assembly according to Claim 22, wherein the 3 distinct light beams are red, green, and blue, each of which may contain other parts of the spectrum at different portions of the corresponding pathlength.

24. The prism assembly according to Claim 15, further comprising an air bubble in the optical coupling fluid.

25. The prism assembly according to Claim 24, wherein said air bubble is outside of optical pathlengths through the prism assembly.

26. The prism assembly according to Claim 15, further comprising a bladder disposed in the optical coupling fluid.

27. The prism assembly according to Claim 26, wherein said bladder is filled with air.

28. The prism assembly according to Claim 26, wherein said bladder is filled with a flexible expansion/contraction material.

29. The prism assembly according to Claim 26, wherein:

said set of optical components comprises 4 Polarizing Beam Splitter (PBS) components arranged in a rectangular shape with one PBS at each corner, a pathlength matching space between each adjacent PBS, and a central fill area centrally located between each PBS; and

said bladder is disposed in the central fill area outside optical pathlengths through the prism assembly.

30. The prism assembly according to Claim 26, wherein:

said set of optical components comprises 4 Polarizing Beam Splitter (PBS) components arranged in a rectangular shape with one PBS at each corner, a pathlength matching space between each adjacent PBS, and a central fill area centrally located between each PBS; and

said prism assembly further comprises a cap configured to cover and seal the central fill area.

31. The prism assembly according to Claim 15, wherein the optical coupling fluid is maintained between the optical components, the seal, and the baseplate.

32. The prism assembly according to Claim 15, further comprising a tube having an open end and a closed end, the open end in contact with the optical coupling fluid; and

an air bubble disposed inside the tube.

33. The prism assembly according to Claim 15, further comprising:

an open ended tube having a first end and a second end, the first end in contact with the optical coupling fluid, and the second end open to the exterior of the prism assembly;

a sealed movable piston disposed in said tube, said piston configured to move because of expansion and contraction of the optical coupling fluid.

34. The prism assembly according to Claim 33, further comprising at least one stop configured to limit motion of the piston.

35. The prism assembly according to Claim 15, further comprising a diaphragm disposed and sealed over an opening to the optical coupling fluid.

36. A High Definition Monitor comprising:

a white light source;

a set of reflective microdisplays;

a prism assembly configured to separate white light from the white light source into component light beams and direct each component light beam to one of the reflective microdisplays and then recombine the reflected component light beams to an output beam;

a lens for projecting the output beam; and a screen for displaying the projected output beam when said prism assembly comprises a set of pathlength matched optical components and coupling fluid interspersed between the optical components.

37. The High Definition Monitor according to Claim 36, wherein the component light beams are red, green, and blue.

38. The High Definition Monitor according to Claim 36, wherein said High Definition Monitor is part of an HDTV.

39. The High Definition Monitor according to Claim 36, further comprising electronics to control the microdisplays.

40. The High Definition Monitor according to Claim 36, wherein the coupling fluid comprises an optical coupling fluid having an index of refraction equivalent to an index of refraction of the optical components.

41. The High Definition Monitor according to Claim 36 beam splitter.

42. The High Definition Monitor according to Claim 36, wherein said optical components comprise at least one of a polarizing beam splitter, a polarization sensitive reflective beam splitter, and a one way reflective beam combiner.

43. A method of constructing a prism assembly, comprising the steps of:
fixing a set of optical components to a baseplate;
sealing spaces between the optical components; and
filling spaces between the optical components with an optical coupling fluid.

44. The method according to Claim 43, wherein the optical coupling fluid is at least one of mineral oil and other fluid having an index of refraction within 25% of the index of refraction of the optical components.

45. The method according to Claim 43, suspending spacers in the optical coupling fluid.

46. The method according to Claim 43, further comprising the steps of coating planar optical components with the optical coupling fluid; and inserting the planar optical elements between the optical components.

47. The method according to Claim 43, wherein said step of fixing comprises the steps of:

arranging the optical components in a pathlength matched configuration; and attaching the pathlength matched configuration to the baseplate.

48. The method according to Claim 47, wherein said step of attaching comprises glueing the pathlength matched configuration to the baseplate.

49. The method according to Claim 43, further comprising the step of: installing an expansion compensation device in the prism assembly.

50. The method according to Claim 49, wherein said expansion compensation device comprises a bladder filled with a flexible substance.

51. The method according to Claim 49, wherein said expansion compensation device comprises an open ended tube having a slide piston.

52. The method according to Claim 49, wherein said expansion compensation device comprises a flexible diaphragm sealed over an opening into the prism assembly optical coupling fluid.

53. The method according to Claim 49, wherein said expansion compensation device comprises a tube having an open end in contact with the optical coupling fluid and a closed end holding an air bubble.

54. The method according to Claim 49, wherein said expansion compensation device comprises an air bubble disposed in the optical coupling fluid.

55. The method according to Claim 43, further comprising the step of inserting planar optical elements between the optical components.

56. The method according to Claim 43, further comprising the step of inserting planar optical elements between the optical components;

wherein said step of filling comprises filing spaces between the optical components with an optical coupling fluid having spacers suspended in the optical coupling fluid.

57. The method according to Claim 43, wherein said optical components comprise 4 Polarizing Beam Splitter (PBS) devices arranged in a pathlength matched rectangular shape.

58. The method according to Claim 43, wherein said step of sealing comprises fixing a frame around each of the optical components.

59. The method according to Claim 43, wherein said step of sealing comprises applying adhesive between each of the optical components.

60. The method according to Claim 43, wherein said step of filling spaces comprises injecting optical coupling fluid using any of a syringe or other tub based injection system.

61. The method according to Claim 47, wherein said step of arranging the optical components comprises setting the optical components in a tool having blocks that set outside dimensions of the prism assembly.

62. The method according to Claim 61, wherein said blocks comprise corner pieces, each corner piece configured to position outside surfaces of one of the optical components.

63. The method according to Claim 61, wherein at least one of said blocks include an airduct configured to apply a vacuum to the optical component set in the airducted block and hold the optical component firmly against the airducted block.

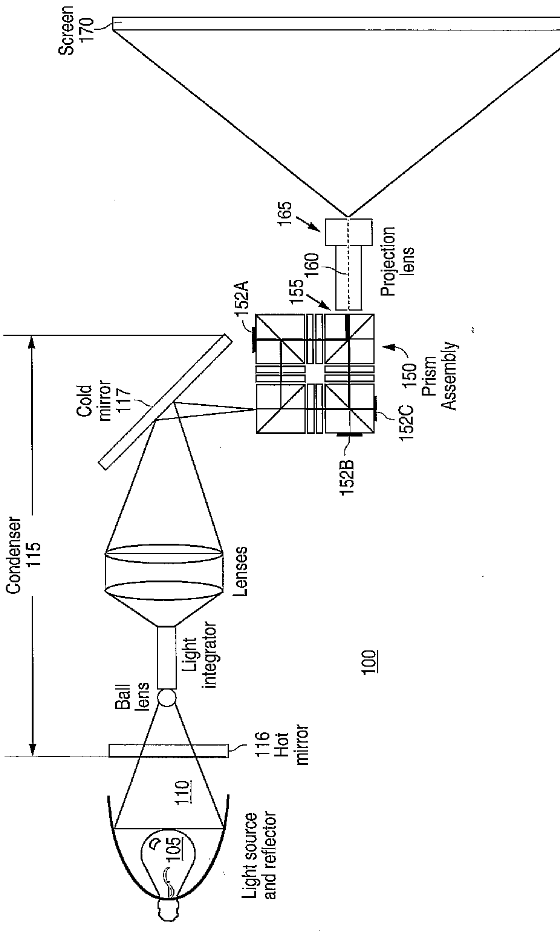
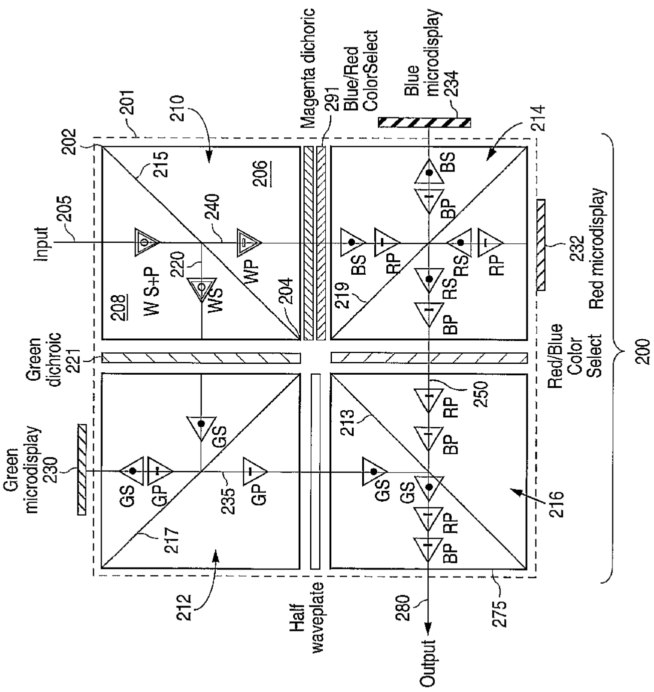

Screen
170
165
Projection
lens
160
155
152A
150
Prism
Assembly
152C
152B
Cold
mirror
117
Condenser
115
Lenses
Light
integrator
Ball
lens
116
Hot
mirror
110
105
Light source
and reflector
100

FIG. 1

FIG. 2


Input
205
201
202
210
215
206
240
220
208
W S+P
WS
WP
204
Magenta dichroic
291
Blue/Red
ColorSelect
Blue
microdisplay
234
214
BS
BP
RP
RS
219
232
Red microdisplay
Green
dichroic
221
Green
microdisplay
230
GS
GP
235
217
212
213
250
216
Red/Blue
Color
Select
200
Half
waveplate
280
Output
275

3/13

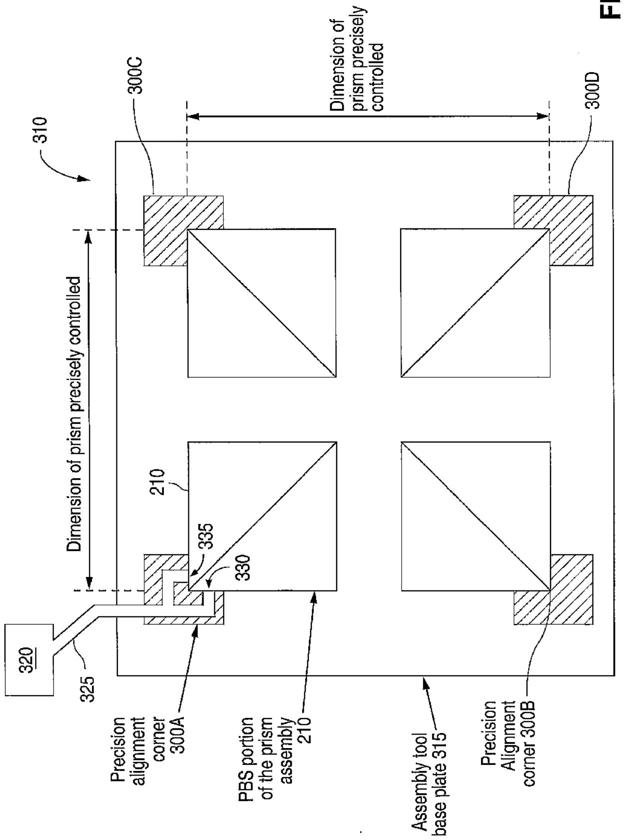
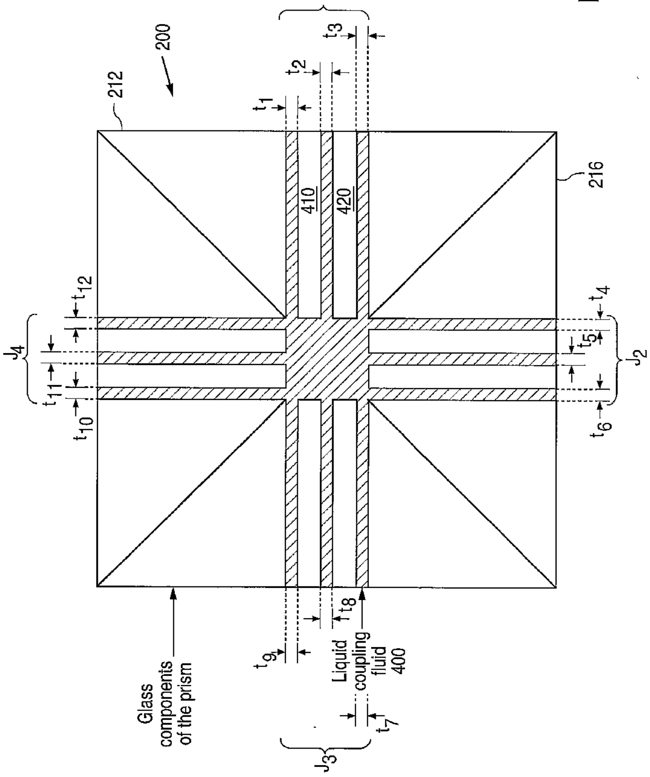

310
300C
Dimension of prism precisely controlled
300D
Dimension of prism precisely controlled
210
335
330
320
325
Precision alignment corner 300A
PBS portion of the prism assembly 210
Assembly tool base plate 315
Precision Alignment corner 300B

FIG. 3

FIG. 4


200
212
216
410
420
J1
J2
J3
J4
t1
t2
t3
t4
t5
t6
t7
t8
t9
t10
t11
t12
Liquid coupling fluid 400
Glass components of the prism

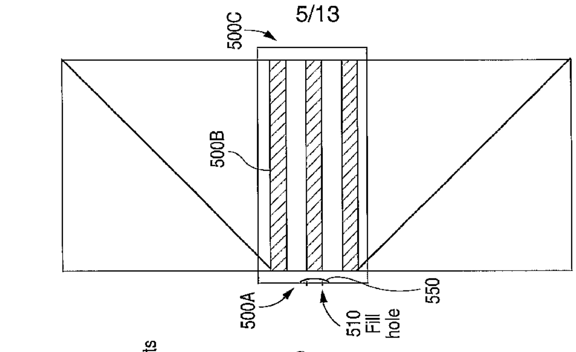

500C
500B
500A
510
Fill
hole
550

FIG. 5B

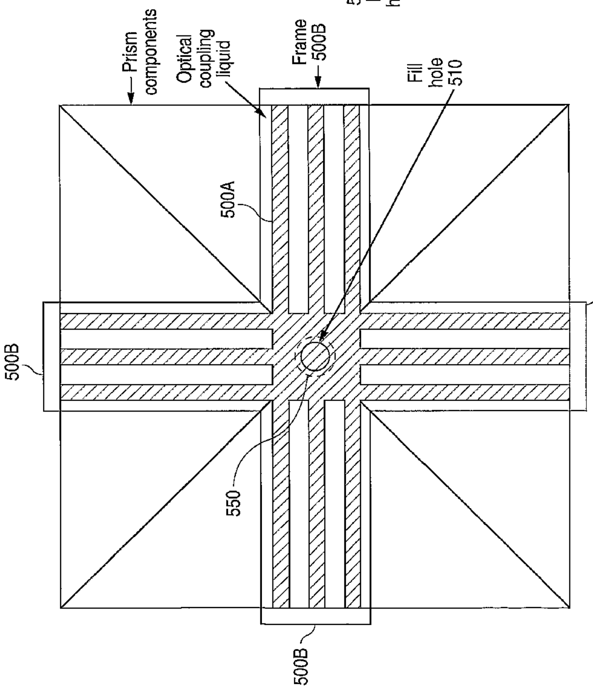

Prism
components
Optical
coupling
liquid
Frame
500B
Fill
hole
510
500A
500B
500B
550
500B

FIG. 5A

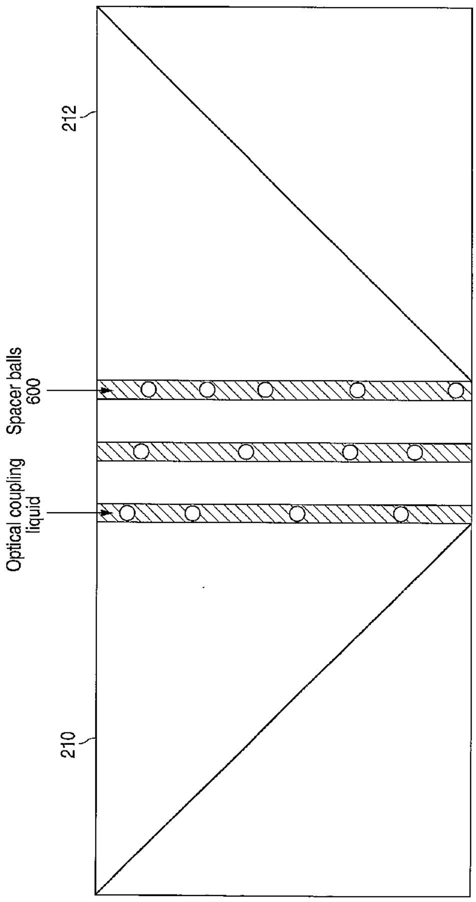


FIG. 6

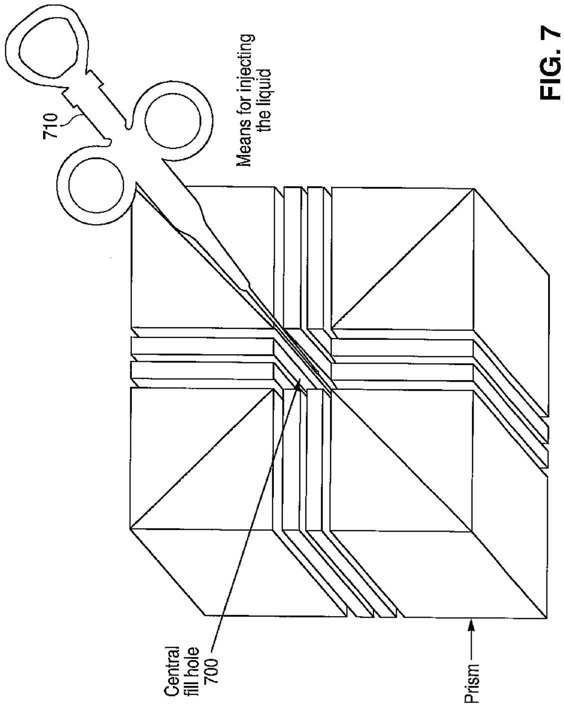

710
Means for injecting the liquid
Central fill hole 700
Prism

FIG. 7

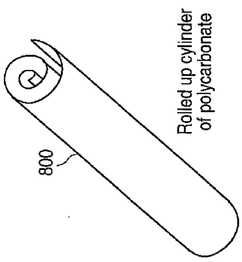

800
Rolled up cylinder
of polycarbonate

FIG. 8B

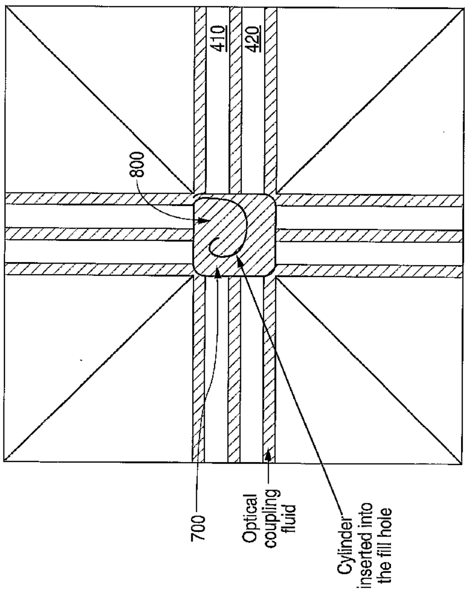

410
420
800
700
Optical
coupling
fluid
Cylinder
inserted into
the fill hole

FIG. 8A

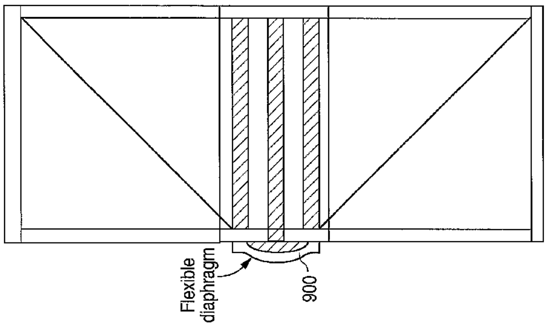


FIG. 9B

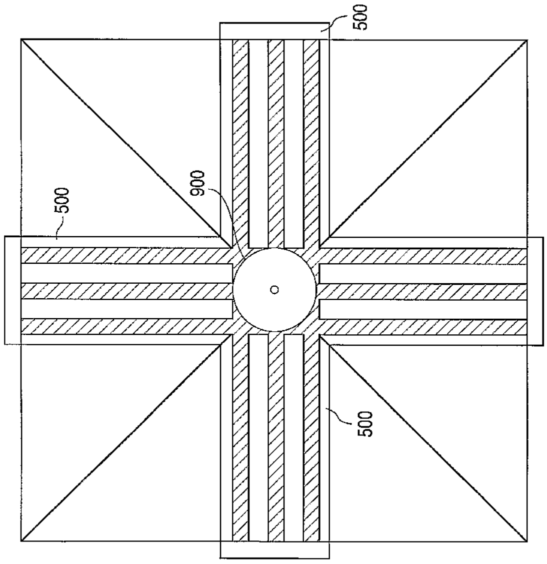


FIG. 9A

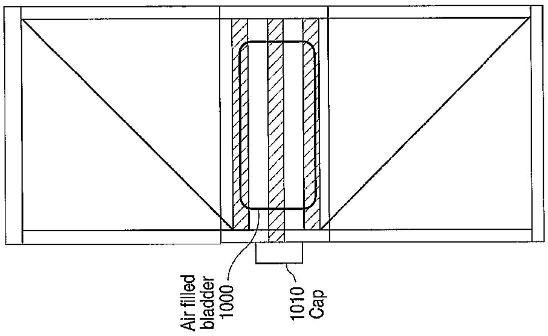


FIG. 10B

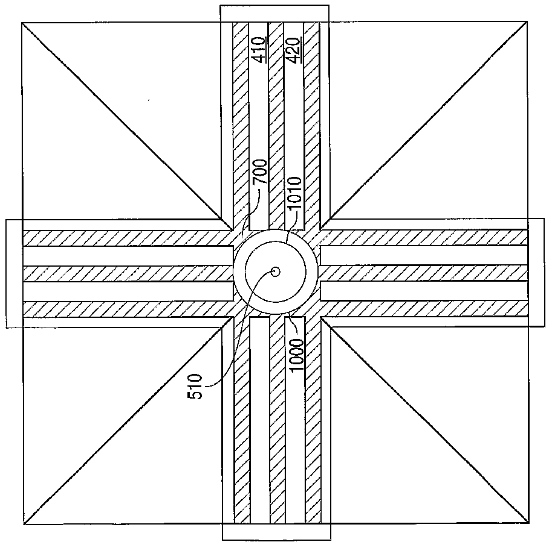


FIG. 10A

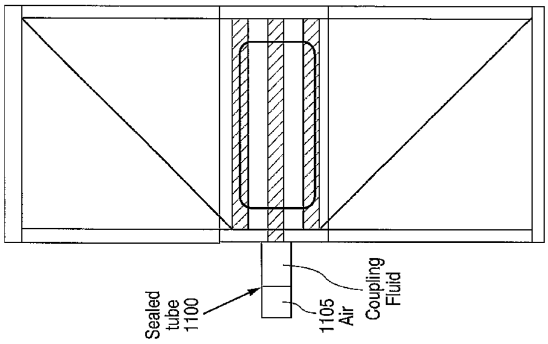


FIG. 11B

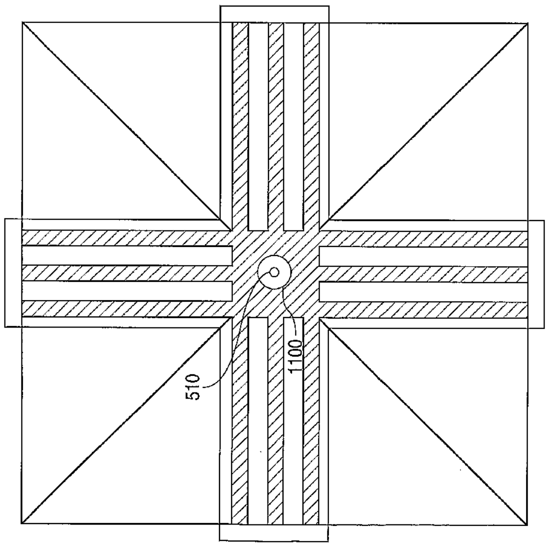


FIG. 11A

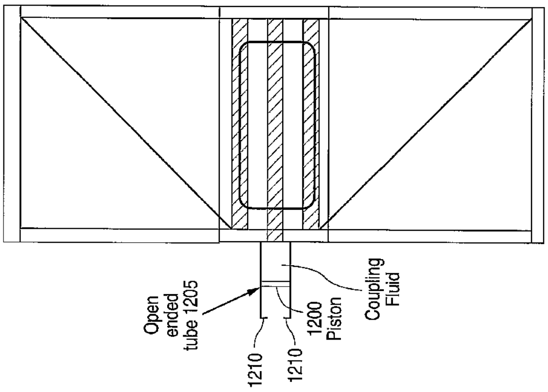


FIG. 12B

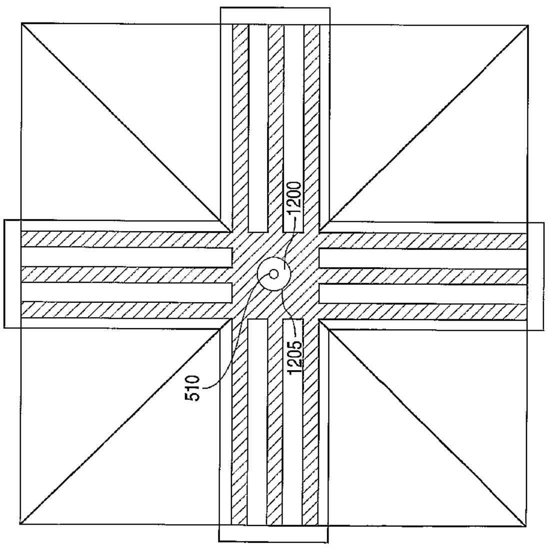


FIG. 12A

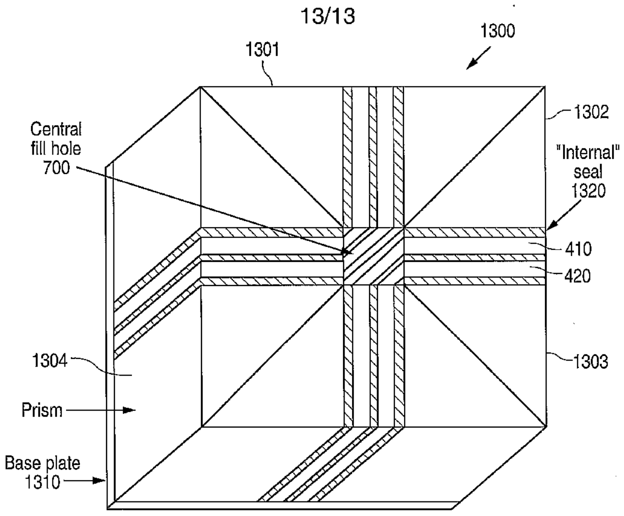

1300
1301
1302
Central fill hole 700
"Internal" seal 1320
410
420
1304
1303
Prism
Base plate 1310

FIG. 13

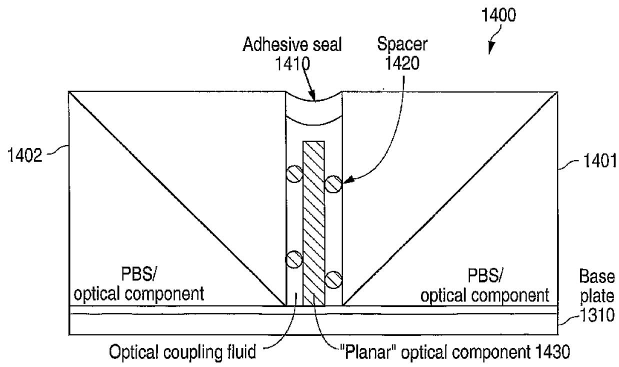

1400
Adhesive seal 1410
Spacer 1420
1402
1401
PBS/ optical component
PBS/ optical component
Base plate 1310
Optical coupling fluid
"Planar" optical component 1430

FIG. 14

【国際調査報告】

INTERNATIONAL SEARCH REPORT

International application No. PCT/US02/25900

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :Please See Extra Sheet.
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 359/618, 627, 634, 639, 640, 488, 495, 256, 637, 638, 497; 353/31, 33, 34, 119, 37, 38; 349/ 5, 8, 9, 7, 10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,544,237 A (GAGNON) 01 October 1985, (01/10/1985) col. 3, line 34 to col. 6, line 44.	1-631-
&,P	US 2002/0001135 A1 (BERMAN et al) 03 January 2002, (03/01/2002) col. paragraph 0007 to col. 9, paragraph 0075.	1-63
A	US 6,139,154 A (HABA) 31 October 2000, (31/10/2000) col. 2, line 25 to col. 11, line 63.	1-631-
A,P	US 6,309,071 B1 (HUANG et al) 30 October 2001, (30/10/2001) col. 2, line 30 to col. 7, line 36.	1-631-

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 OCTOBER 2002	31 DEC 2002

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-7724

Authorized officer
LOHA BEN
Telephone No. 703-308-4820

Form PCT/ISA/210 (second sheet) (July 1998)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/25900

A. CLASSIFICATION OF SUBJECT MATTER:
IPC (7):

G02B 27/10, 27/12, 27/14; G03B 21/00, 21/26; G02F 1/03, 1/1335

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

359/618, 627, 634, 639, 640, 488, 495, 256; 353/31, 33, 34, 119; 349/ 5, 8, 9

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

EAST: microdisplay$3 SAME polariz$5 SAME reflect$4 SAME project$3 SAME prism$1
WEST: prism$1 SAME polarizing ADJ beam ADJ splitter$1 and dichroic WITH filter$3 and coupl$3 WITH (fluid$5 or liquid or air) SAME polariz$5

フロントページの続き

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(32)優先日　　　　　平成14年7月24日(2002.7.24)
(33)優先権主張国　　米国(US)

(81)指定国　　　　　AP(GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZM,ZW),EA(AM,AZ,BY,KG,KZ,MD,RU,TJ,TM),EP(AT,BE,BG,CH,CY,CZ,DE,DK,EE,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE,SK,TR),OA(BF,BJ,CF,CG,CI,CM,GA,GN,GQ,GW,ML,MR,NE,SN,TD,TG),AE,AG,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,BZ,CA,CH,CN,CO,CR,CU,CZ,DE,DK,DM,DZ,EC,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KP,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,MZ,NO,NZ,OM,PH,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TN,TR,TT,TZ,UA,UG,UZ,VC,VN,YU,ZA,ZM,ZW

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　　　　　　アメリカ合衆国　カリフォルニア州　９５０３３　ロスガトス　フェイバー　リッジ　ロード　１８６４４

Ｆターム(参考) 2H043 AA03 AA06 AA24 AB09 AD03 AD06 AD16 AD21 AE02 AE09
　　　　　　　　　　BA03
　　　　　　　　2H049 BA05 BA43 BB02 BB51 BB65 BB66 BC14 BC22
　　　　　　　　2K103 AA01 AA14 AB10 BC01 BC07 BC12 BC15 BC51 CA18 CA26
　　　　　　　　　　CA29 CA75