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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

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(54) **Title**: ATHERMALIZED PERMANENT-ALIGNMENT OPTICAL-ELEMENT MOUNT

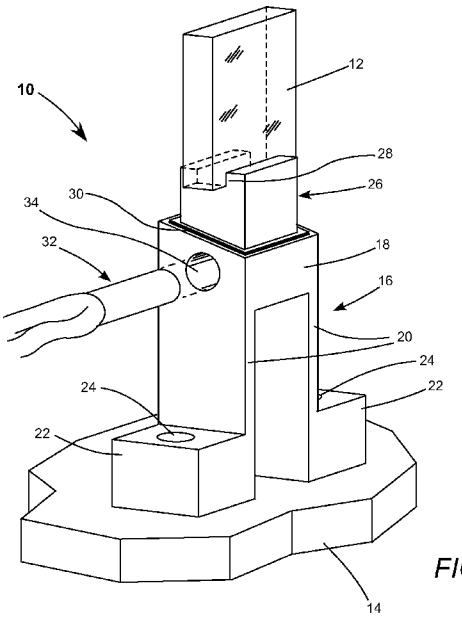

FIG. 1

(57) **Abstract**: A mounting fixture for mounting an optical element on a base-plate has spaced-apart parallel legs attachable by brackets to the base-plate and a mounting platform attached to the legs. The platform can be heated by a removable heater. The optical element is held in a mounting tab attached to the platform by a solder-pad. Heating the platform softens the solder- pad allowing the tab and the element to be aligned. Removing the heat allows the pad to harden to complete the attachment and retain the alignment of the element on the mount.

ATHERMALIZED PERMANENT-ALIGNMENT OPTICAL-ELEMENT MOUNT

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates in general to mounting fixtures for optical elements. The invention relates in particular to optical element mounts that provide for alignment of an optical element during manufacture of optical apparatus such as a laser, but which leave the element essentially permanently aligned following the manufacturing alignment.

DISCUSSION OF BACKGROUND ART

[0002] Laser apparatus sold commercially typically includes a plurality of optical elements. Such optical elements include resonator mirrors, beam-steering mirrors, and lenses for focusing or collimating a beam. Most such elements require precise alignment during manufacture of the device, but it is desirable that after this manufacturing alignment is complete the elements stay essentially permanently aligned.

[0003] Typical methods for "permanent" alignment of optical elements involve attaching an optical element to a mount or pedestal using a hard-curable adhesive, such as an epoxy, or using a solder bond. In such methods, the optical element is on the mount while the adhesive is soft and uncured or while the solder is in a thermally softened, at least partially molten, condition. After alignment is complete, the adhesive is allowed to cure, or the solder is allowed to solidify. Solder-bonding is preferred as adhesives can create problems traceable to out-gassing products of the adhesives.

[0004] One effective solder-bonding method for an optical element is described in U.S. Patent No. 5,930,600, assigned to the assignee of the present invention. In this method, a positive thermal coefficient thermistor (PCT) is supplied with a constant current to heat the PCT and soften the solder used for bonding. The PCT is bonded to a pedestal attachable to a base-plate on which the optical element is to be mounted. The optical element is bonded on a pedestal attached to the PCT and which can be aligned when the solder is soft. Once the alignment is

complete, current to the PCT is cut off and the solder solidifies, maintaining the optical-element in the optical alignment.

[0005] While this method is effective and has been verified as reliable through several years of commercial use, the method nevertheless has certain shortcomings. One shortcoming is simply the cost of the PCT, which remains part of the optical element mount once the alignment is completed, yet has no further useful function. Another shortcoming is that two solder bonds are required in the mount. Yet another shortcoming is that careful selection of metal parts is required such that there is an acceptable coefficient of thermal expansion (CTE) match between the mount and the optical element, and between the mount and the base-plate. There is need for a an optical element mount that allows a mounting method similar in principle to that of the '600 patent while at least mitigating, if not altogether eliminating, the above described shortcomings thereof.

SUMMARY OF THE INVENTION

[0006] The present invention is directed to mounting and aligning an optical element in optical apparatus such as a laser. In one aspect apparatus in accordance with the present invention comprises a base-plate, an optical element, and an element-holding member, fixedly holding the optical element. A pedestal is provided having a platform-portion for supporting the element-holding member and having spaced-apart legs extending from the platform-member and attached to the base-plate. The element-holding member is attached to the platform-portion of the pedestal by a solder layer. The platform-portion of the pedestal is temporarily heatable by a removable heat-source to soften the solder layer for aligning the element-holding member on the platform-portion of the pedestal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The accompanying drawings, which are incorporated in and constitute a part of the specification, schematically illustrate a preferred embodiment of the present invention, and together with the general description given above and the detailed description of the preferred embodiment given below, serve to explain principles of the present invention.

[0008] FIG. 1 schematically illustrates a preferred embodiment 10 of an optical-element mount in accordance with the present invention including an element-holding tab solder-bonded to a mounting-pedestal, the pedestal having a platform heatable by a removable heat-source, the platform having two spaced apart legs attached thereto, the legs being attachable to a base-plate.

DETAILED DESCRIPTION OF THE INVENTION

[0009] Referring now to the drawings, wherein like components are designated by like reference numerals, FIG. 1 schematically illustrates a preferred embodiment 10 of an optical-element mount in accordance with the present invention. Here, an optical element 12, to be mounted on a base-plate 14, is fixedly bonded prior to alignment in a slot 28 in an element-holding tab 26. This fixed bonding can be accomplished by either adhesive bonding or solder bonding.

[0010] Element-holding tab 26 is supported via a solder pad 30 on a platform or bridge portion 18 of a mounting-pedestal 16. Bridge portion 18 has two elongated spaced apart legs 20 attached thereto. Legs 20 are attachable to base-plate 14 via brackets 22, one attached to each of the two legs. The brackets, and, accordingly, mounting pedestal 16, are secured to the base plate, for example by bolts or screws (not shown) extending through holes 24 in the brackets into or through the base-plate. Attachment of the pedestal to the base-plate takes place before final mounting of element-holding tab 26 (and element 12 therein) to the mounting pedestal.

[0011] Platform portion 18 of pedestal 16 is heatable by a temporary heat source. Here, the heat-source is an electrically powered cylindrical cartridge-type heater 32 which is a loose fit in a cylindrical hole or bore 34 extending into or through platform portion 18 of the pedestal. One suitable cartridge heater is a model H050-15-24-01 available from Sun Electric Heater Company of Salem, Massachusetts. In an exemplary mounting operation, heater 32 is inserted into bore 34. Bridge (platform portion) 18 of pedestal 16 is heated sufficient to soften solder 30, but not sufficient to adversely affect the attachment of the optical element to the element holding tab. Optical element 12 is then aligned manually by adjusting tab 26 on the softened solder pad. Once the element is aligned electric power to the cartridge heater is cut-off, allowing solder pad 30 to solidify. The cartridge heater is then removed and can be used for another mounting operation.

[0012] One clear advantage of the inventive optical element mount compared with the prior-art mount of the above referenced 5,930,600 patent is that the heating element is removable after the alignment operation. The one heater can be used for a plurality of mounting operations in a plurality of lasers. In the prior-art method, a heater (PCT) remains with the prior-art mount so there are as many PCTs required as there optical element mounts per laser multiplied by the number of lasers being manufactured.

[0013] Another advantage is that attaching pedestal 16 to base-plate 14 via parallel spaced-apart legs 20 provides that the material of the pedestal and tab 16 can be selected to be material which is CTE compatible with the material of the optical element (for minimizing the CTE mismatch), without regard to the material of base-plate 14. By way of example, Invar is CTE compatible with fused silica elements, and stainless steel is CTE compatible with calcium fluoride (CaF_2) optical elements. Base-plate 14 is typically an aluminum (Al) alloy in commercial lasers. Aluminum has a CTE about 34-times (depending on a particular aluminum alloy) that of Invar and about 2-times that of stainless steel. Shear forces between the base-plate and the pedestal are minimized by flexure of legs 20.

[0014] It was calculated that for a solid pedestal made from Invar made and mounted by two screws to an Aluminum base-plate, a shear-force of 1000 pounds on each screw could result from a temperature change of 40°C. Such a temperature charge could occur during transit of apparatus from a manufacturer to a user and cause misalignment of a mounted element. It was calculated that with a mount in the inventive two-legged configuration, this stress could be reduced to as low as 15 pounds per screw for the same materials and temperature change.

[0015] Yet another advantage is that the relatively thin legs 20 of Invar or stainless steel, which both have a relatively low thermal conductivity result in a relatively low transfer of heat from heater cartridge 32 to the base-plate Experimental results indicate that only roughly half of the heat-load is required for softening solder compared with prior-art, monolithic, PTC-based mounts. This results in less heating of the supporting structure, which reduces wait-times (for cool-down) during the alignment process.

[0016] As seen in Figure 1, in one preferred embodiment, the upper surface of pedestal 18 is canted at an angle with respect to the surface of the base plate 14. The lower surface of the element holding tab 26 has a complimentary angled surface. As can be appreciated, with this geometry, sliding the tab 25 forward and back on the pedestal curing alignment will raise or lower the optical element 12 with respect to the base plate.

[0017] It should be noted here that the inventive mount is not limited to the precise configuration of mount 10 of FIG. 1. Those skilled in the mechanical arts using mechanical and thermal analysis software, such as NASTRAN, available from NEi Software of Westminster, California, can readily modify the configuration to accommodate particular optic shapes sizes and materials, without departing from the spirit and scope of the present invention. Accordingly, the present invention is not limited to the example described and depicted herein. Rather, the invention is limited only by the claims appended hereto.

WHAT IS CLAIMED IS:

1. Optical apparatus, comprising:

a base-plate;

an optical element;

an element-holding member, fixedly holding the optical element;

a pedestal having a platform-portion for supporting the element-holding member and having spaced-apart legs extending from the platform-member and attached to the base-plate; and

wherein the element-holding member is attached to the platform-portion of the pedestal by a solder layer, and the platform-portion of the pedestal is temporarily heatable by a removable heat-source to soften the solder layer for aligning the element-holding member on the platform-portion of the pedestal.

2. The apparatus of claim 1, wherein the removable heat-source is an electrically powered cartridge heater, and the platform-member has a cavity therein for receiving the cartridge heater.

3. The apparatus of claim 1, wherein, there are two-spaced apart legs and each of the legs is attached to the base-plate by a bracket extending outward therefrom.

4. The apparatus of claim 1, wherein the material of the holding-element and the pedestal are selected to minimize thermal coefficient of expansion mismatch with the optical element.

5. The apparatus of claim 4, wherein the optical element is a fused silica optical element and the material of the element-holding member and the pedestal is Invar.

6. The apparatus of claim 5, wherein the base-plate is made from aluminum or an alloy thereof.

7. The apparatus of claim 4, wherein the optical element is a calcium fluoride optical element and the material of the element-holding member and the pedestal is stainless steel.

8. The apparatus of claim 7, wherein the base-plate is made from aluminum or an alloy thereof.

9. A method of mounting an optical element on a base-plate, comprising the steps of:

attaching the optical element fixedly to an element-holding member;

providing a pedestal for supporting the element-holding member, the pedestal having a platform-portion, the platform portion having spaced apart legs extending therefrom;

attaching the pedestal to the base-plate via the spaced apart legs;

placing the element holder on the platform-portion of the pedestal with a solder layer therebetween;

applying heat to the platform-portion of the pedestal sufficient to soften the solder layer;

aligning the element-holding member and the optical element therein on the platform-portion of the pedestal in the softened solder layer; and

discontinuing the application of heat to the platform-portion of the pedestal, thereby allowing the solder layer to solidify and hold the element-holding member in the alignment on the platform portion of the pedestal.

10. The apparatus of claim 9, wherein the heat is applied via an electrically powered heater removably inserted into the platform-portion of the pedestal.

11. A method of mounting an optical element to a base plate comprising the steps of:

attaching a pedestal to the base plate, said pedestal having a planar platform, said pedestal including a cavity for receiving a heating element;

attaching the optical element to an element holding member, the element holding member having a planar surface for mating with the platform of the pedestal;

placing the planar surface of the element holding member into abutting relationship with the platform of the pedestal with an intermediate solder layer therebetween;

inserting a heating element into the cavity of the pedestal to heat the pedestal and the solder layer an amount sufficient to permit the relative movement between the holding member and the pedestal so that optical element can be aligned; and

discontinuing the heating of the solder layer to allow the solder layer to cool and fixing the position of the holding member with respect to the pedestal.

12. A method as recited in claim 11, wherein the platform is oriented in a non-parallel plane with respect to the base plate and the planar surface of the holding member is oriented at an angle such that adjusting the position of the optical element relative to the pedestal will raise or lower the optical element with respect to the base plate.

13. A method as recited in claim 11, wherein the pedestal is U-shaped having a pair of legs that are attached to the base plate.

14. A method as recited in claim 11, further including the step of removing the heating element from the cavity after the optical element has been aligned.

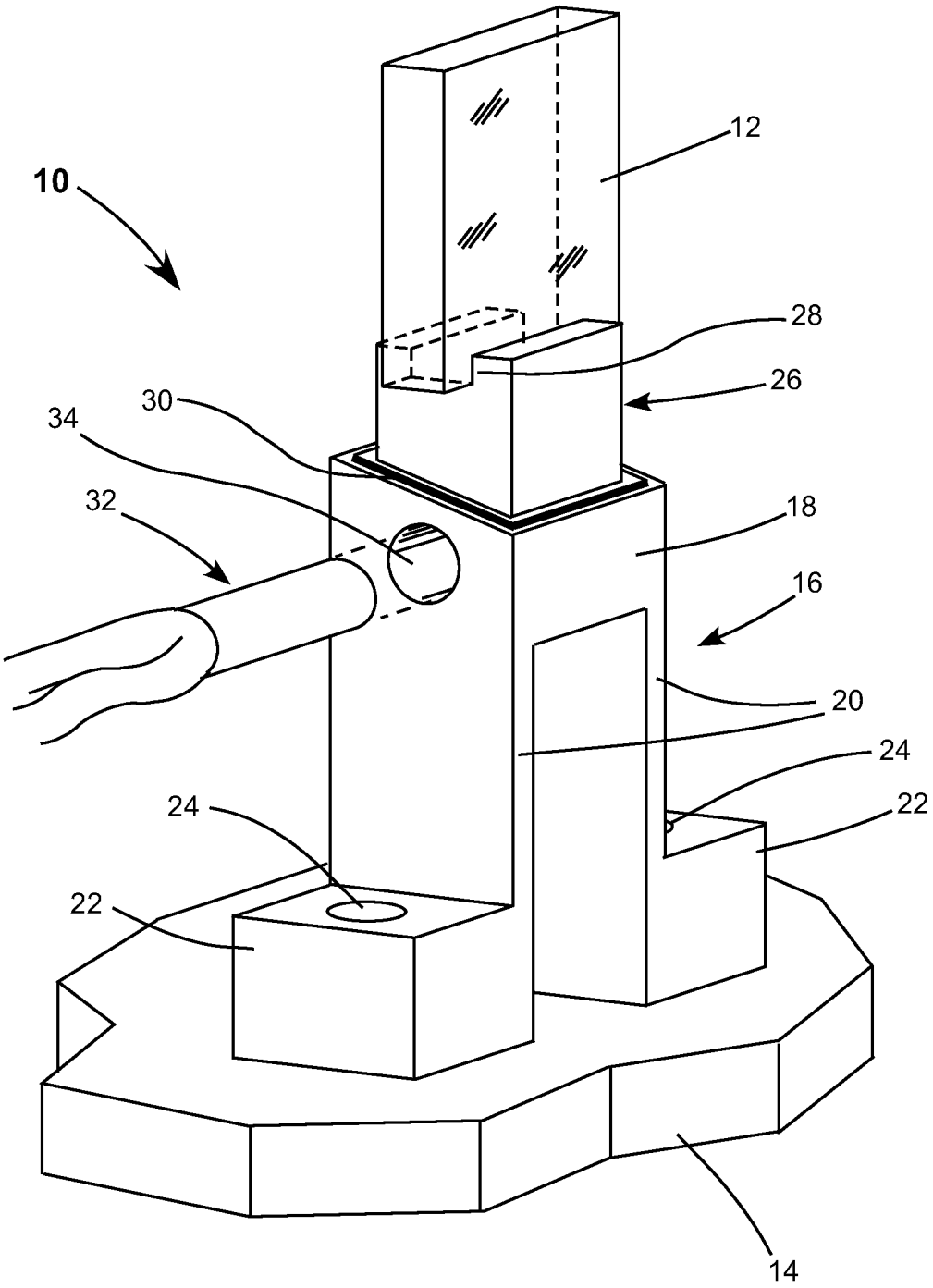

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/023314

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B7/00 G02B7/02 G02B7/18
ADD.

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)
G02B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/047747 A1 (SANO TOMOMI [JP]) 3 March 2005 (2005-03-03)	1,3,9
A	paragraphs [0027] - [0045]; figures 2-4	2,10-14
Y	US 6 094 180 A (MEAD JR RUSSELL C [US] ET AL) 25 July 2000 (2000-07-25) column 2, lines 40-55	1,3,9

☐ 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 application or patent but 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
30 April 2013	17/07/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Stemmer, Michael

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/023314

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-3, 9-14

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-3, 9-14

an optical apparatus where a cartridge heater can be received in a cavity for the purpose of melting a solder during alignment

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2. claims: 4-8

an optical apparatus wherein the material of the holding-element and the pedestal are selected to minimize thermal coefficient of expansion mismatch with the optical element, with the purpose of athermalization

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2013/023314

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005047747 A1	03-03-2005	CN 1591059 A	09-03-2005
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