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(54) ULTRAVIOLET POLARIZATION BEAM SPLITTER WITH MINIMUM APODIZATION

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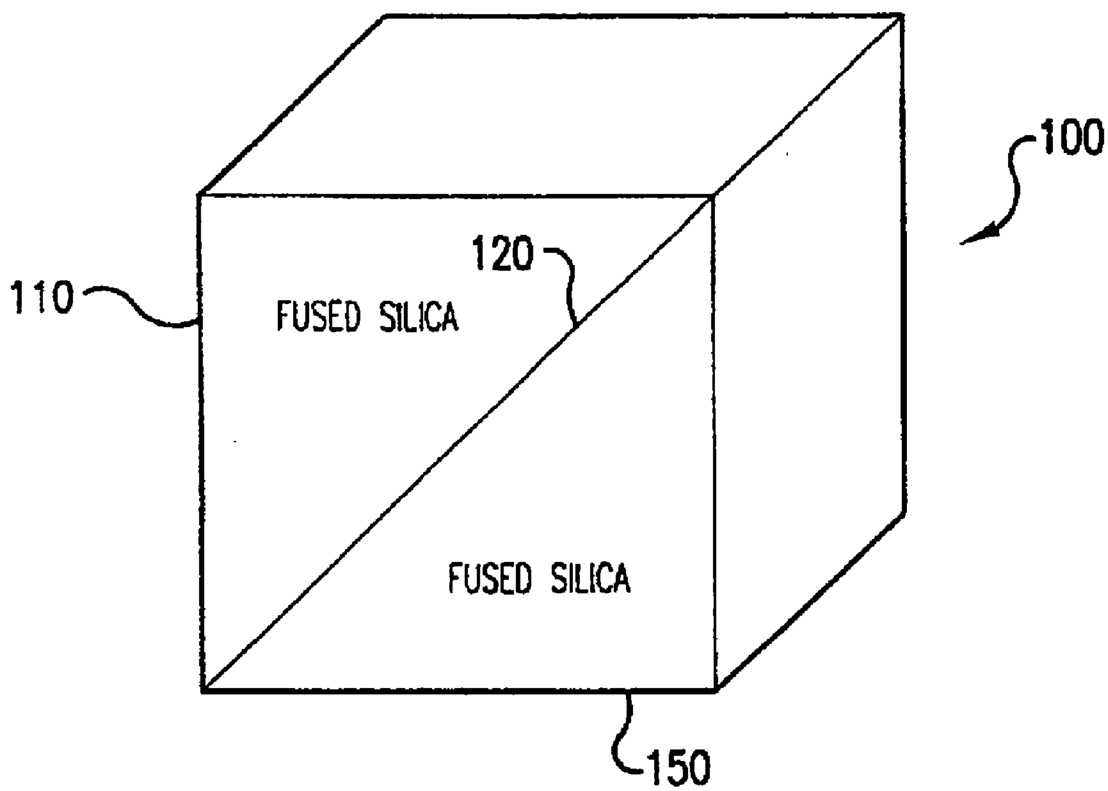
(57) ABSTRACT

A beamsplitter includes a first fluoride prism and a second fluoride prism. A coating interface is between the first and second fluoride prisms, wherein an overall R(s)*T(p) function of the beamsplitter varies no more than ±2.74% in the range of 40-50 degrees of incidence.



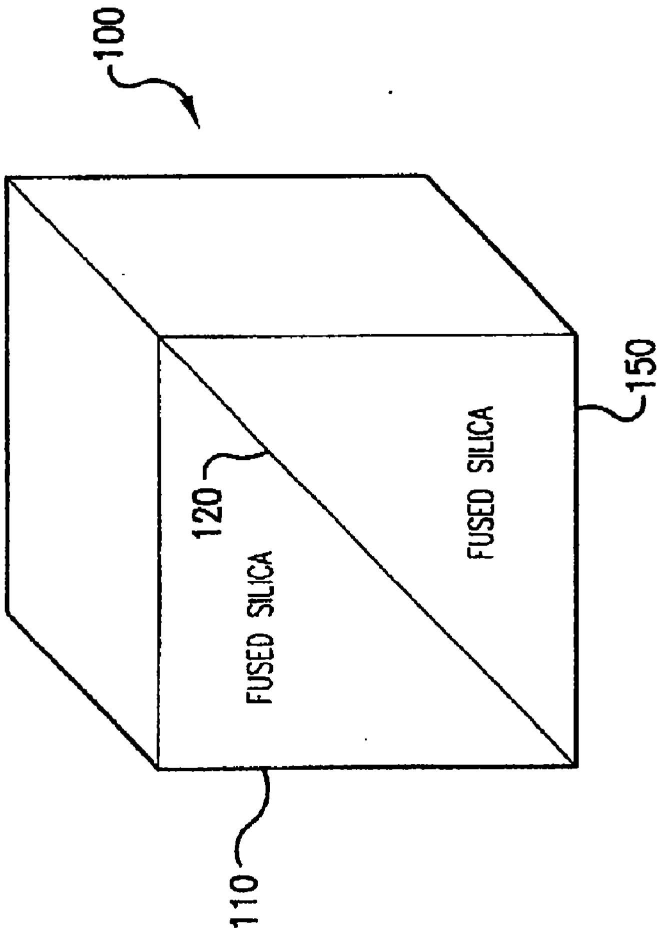


FIG. 1A

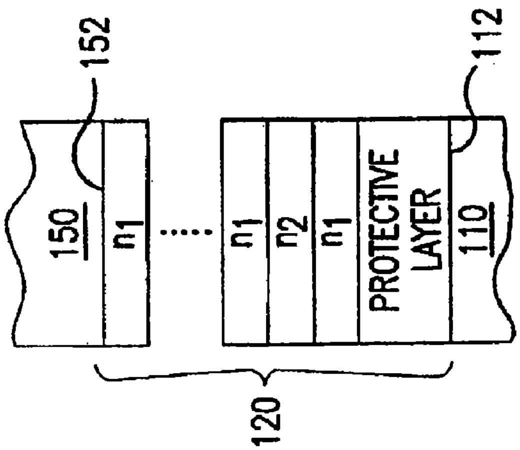


FIG. 1B

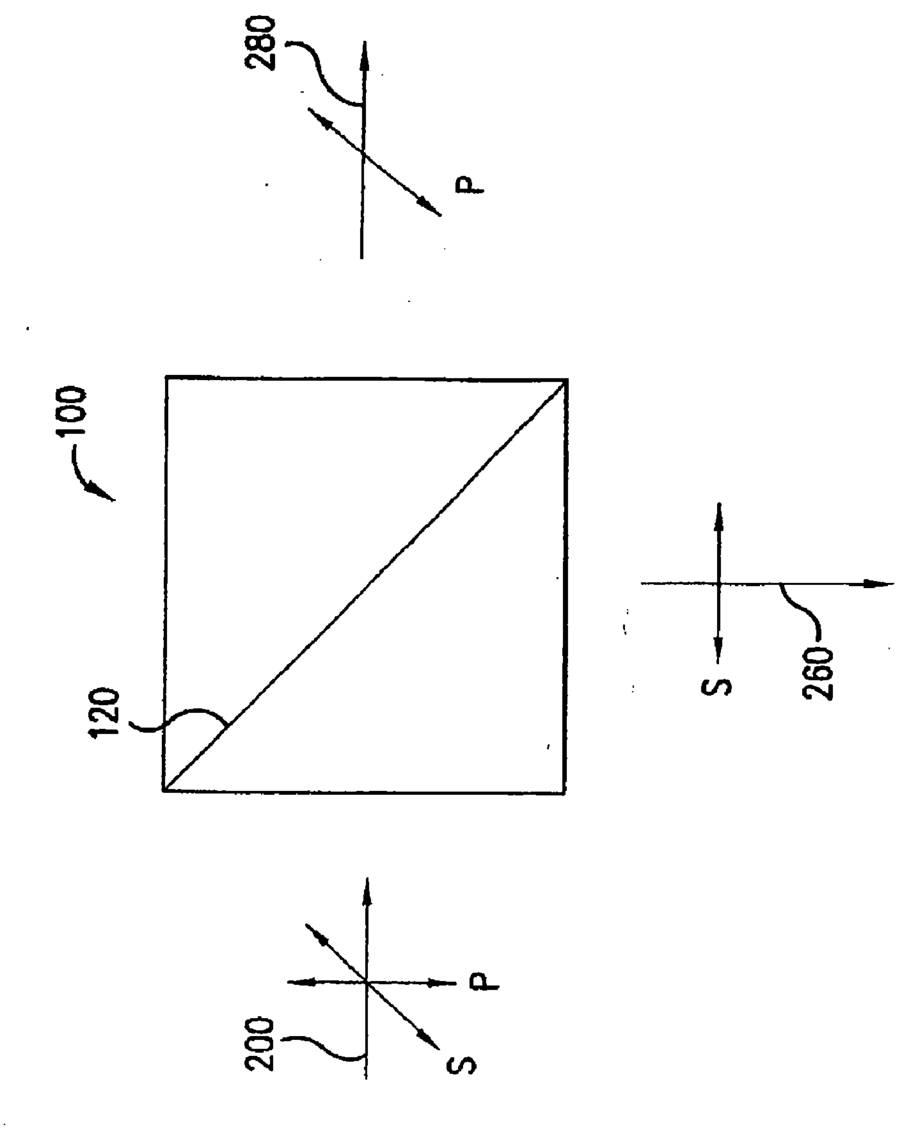


FIG. 2A

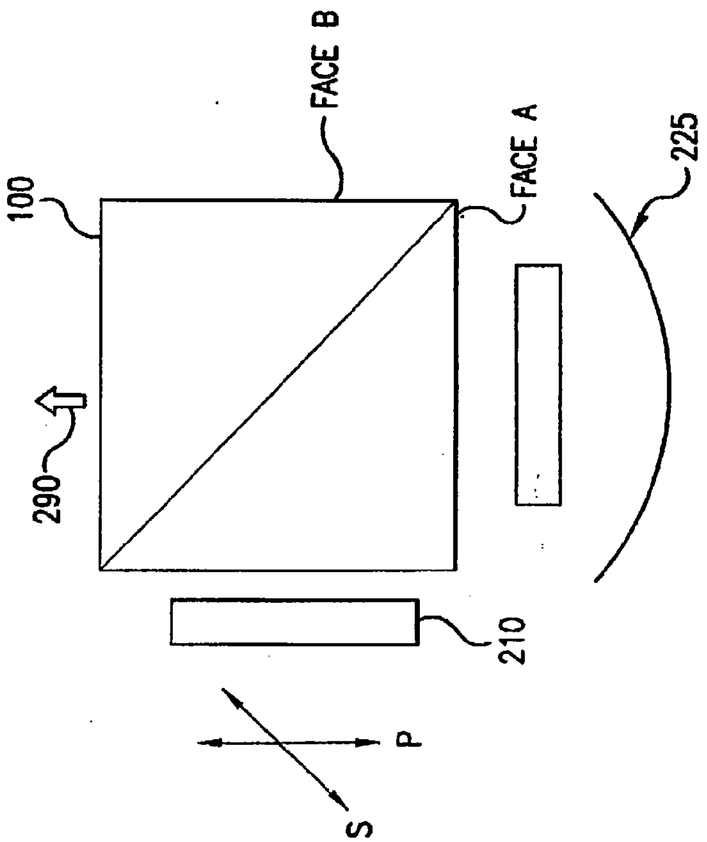


FIG. 2B

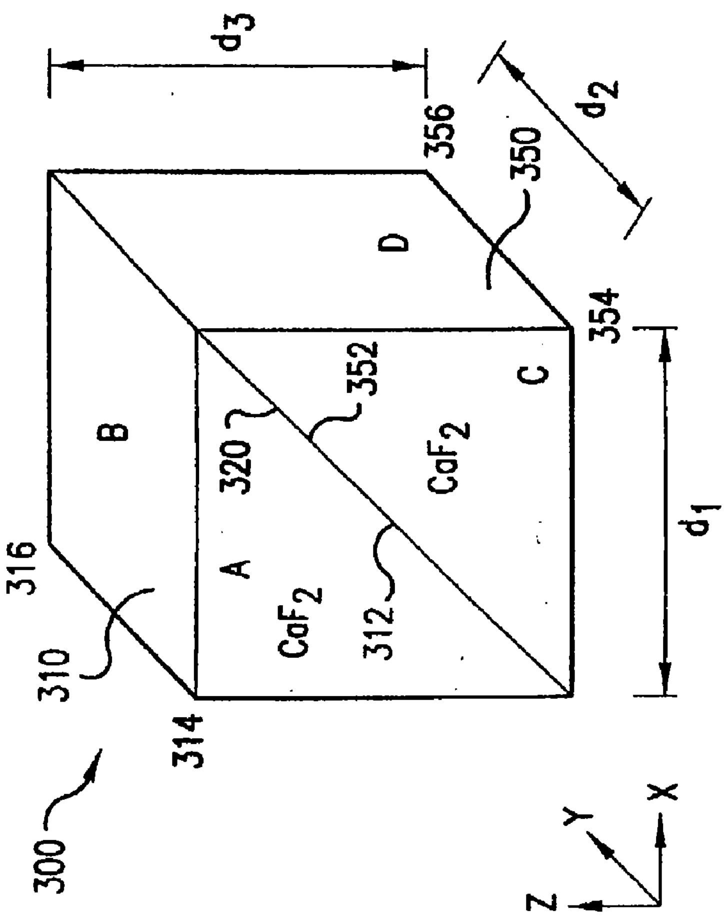

300
310
312
314
316
320
350
352
354
356
A
B
C
D
CaF2
CaF2
d1
d2
d3
X
Y
Z

FIG. 3A

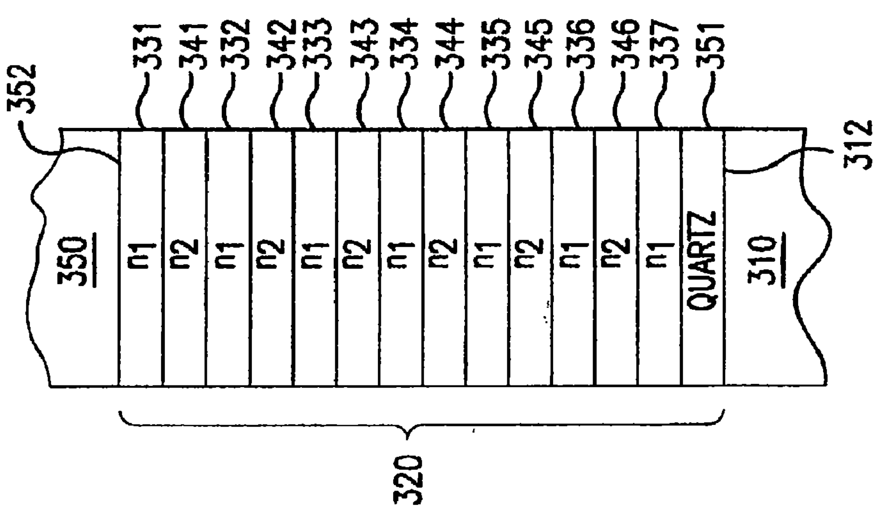

352
331
341
332
342
333
343
334
344
335
345
336
346
337
351
312
350
n1
n2
n1
n2
n1
n2
n1
n2
n1
n2
n1
n2
n1
QUARTZ
310
320

FIG. 3B

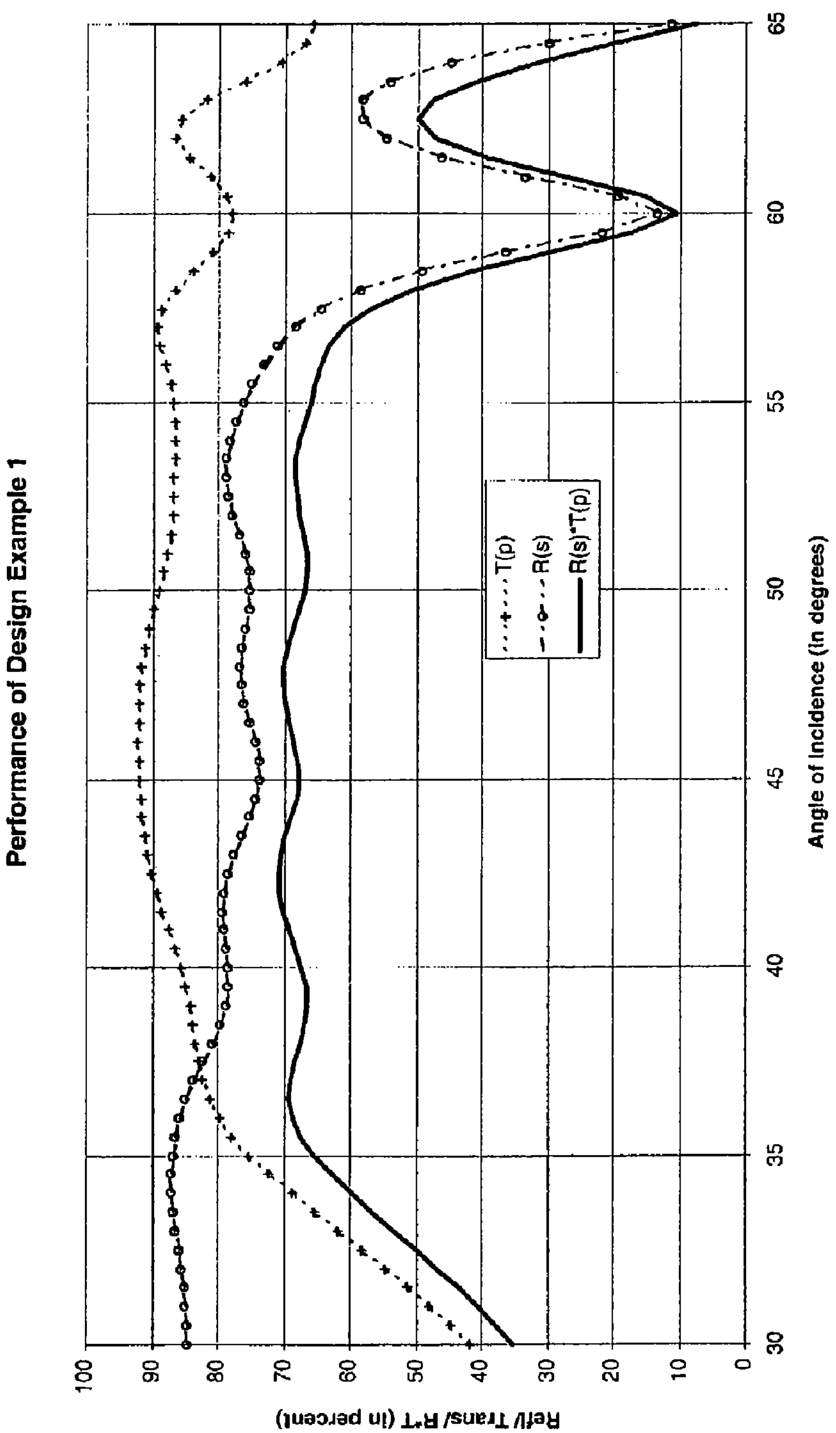

Performance of Design Example 1
Refl/ Trans/ R*T (in percent)
Angle of Incidence (in degrees)
T(p)
R(s)
R(s)*T(p)
0
10
20
30
40
50
60
70
80
90
100
30
35
40
45
50
55
60
65

FIG. 4

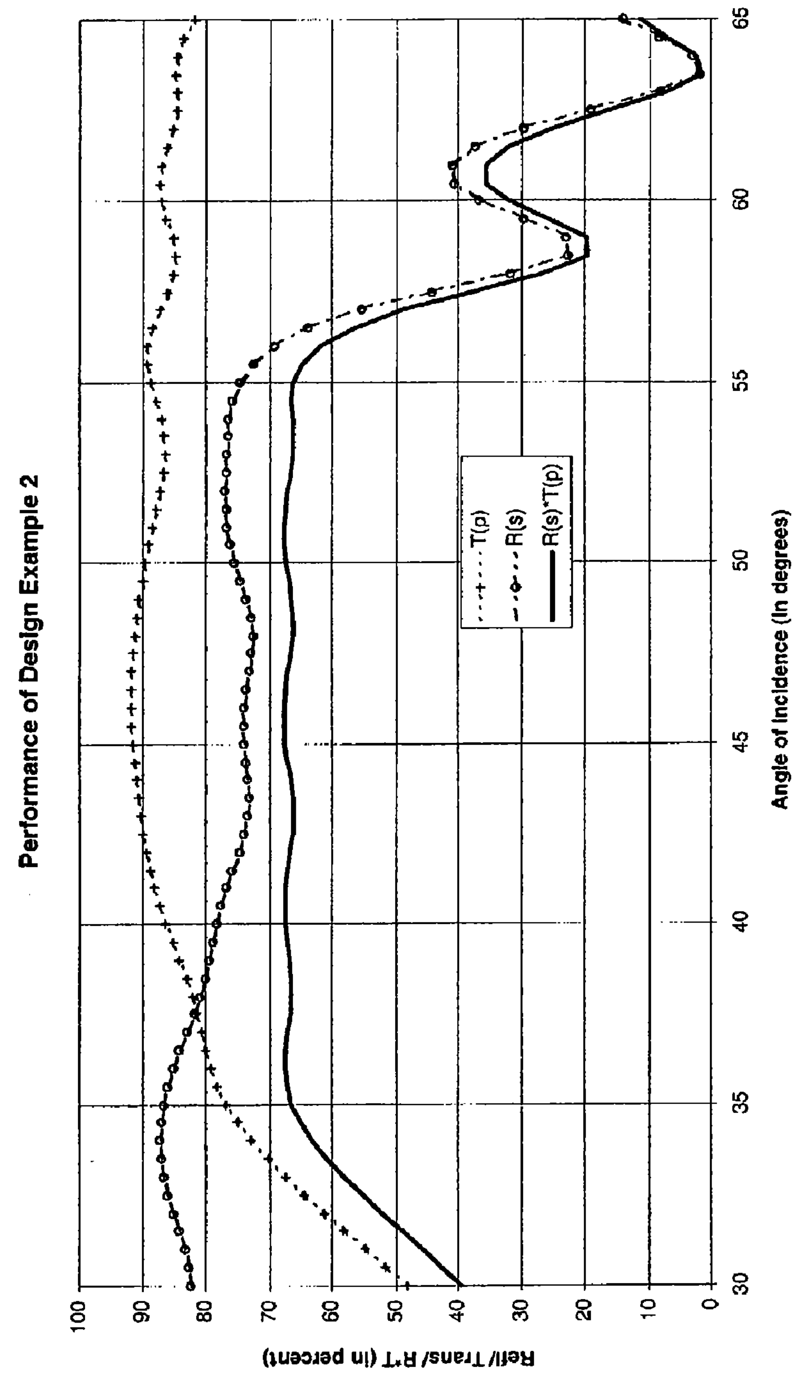

Performance of Design Example 2
Refl/Trans/ R*T (in percent)
Angle of Incidence (in degrees)
T(p)
R(s)
R(s)*T(p)
100
90
80
70
60
50
40
30
20
10
0
30
35
40
45
50
55
60
65

FIG. 5

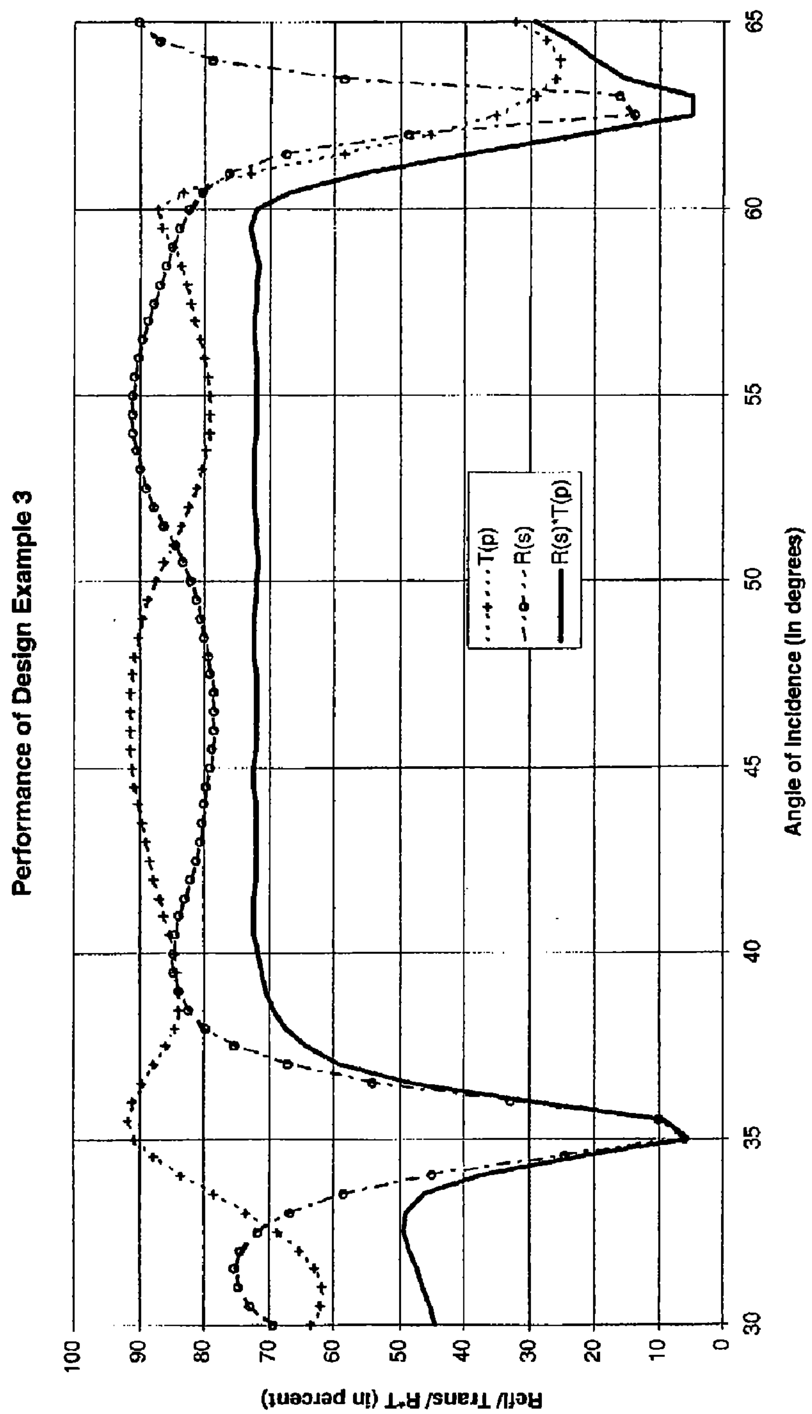

Performance of Design Example 3
Refl/ Trans/ R*T (in percent)
0
10
20
30
40
50
60
70
80
90
100
30
35
40
45
50
55
60
65
Angle of Incidence (In degrees)
T(p)
R(s)
R(s)*T(p)

FIG. 6

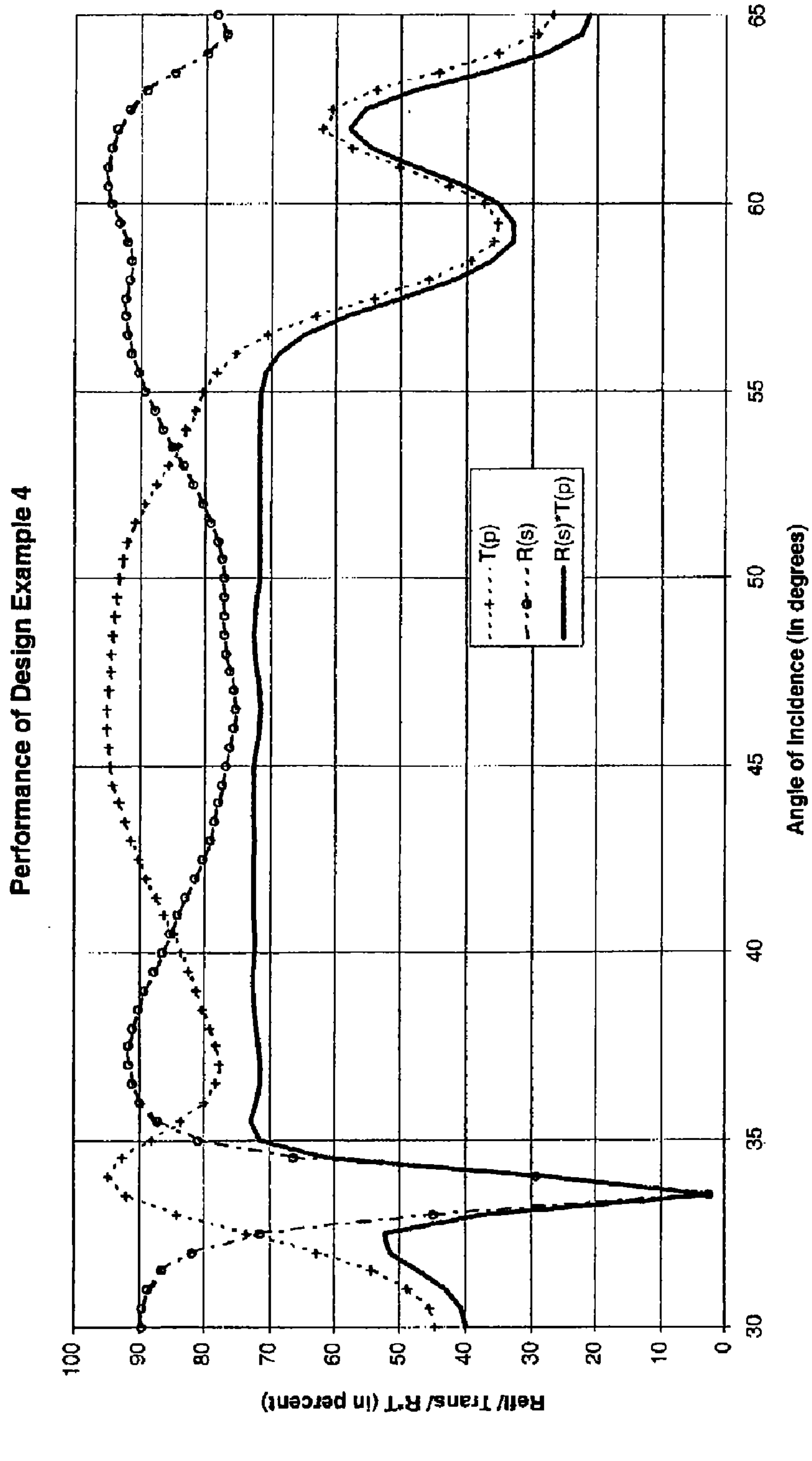

Performance of Design Example 4
T(p)
R(s)
R(s)*T(p)
Refl/ Trans/ R*T (in percent)
Angle of Incidence (in degrees)
100
90
80
70
60
50
40
30
20
10
0
30
35
40
45
50
55
60
65

FIG. 7

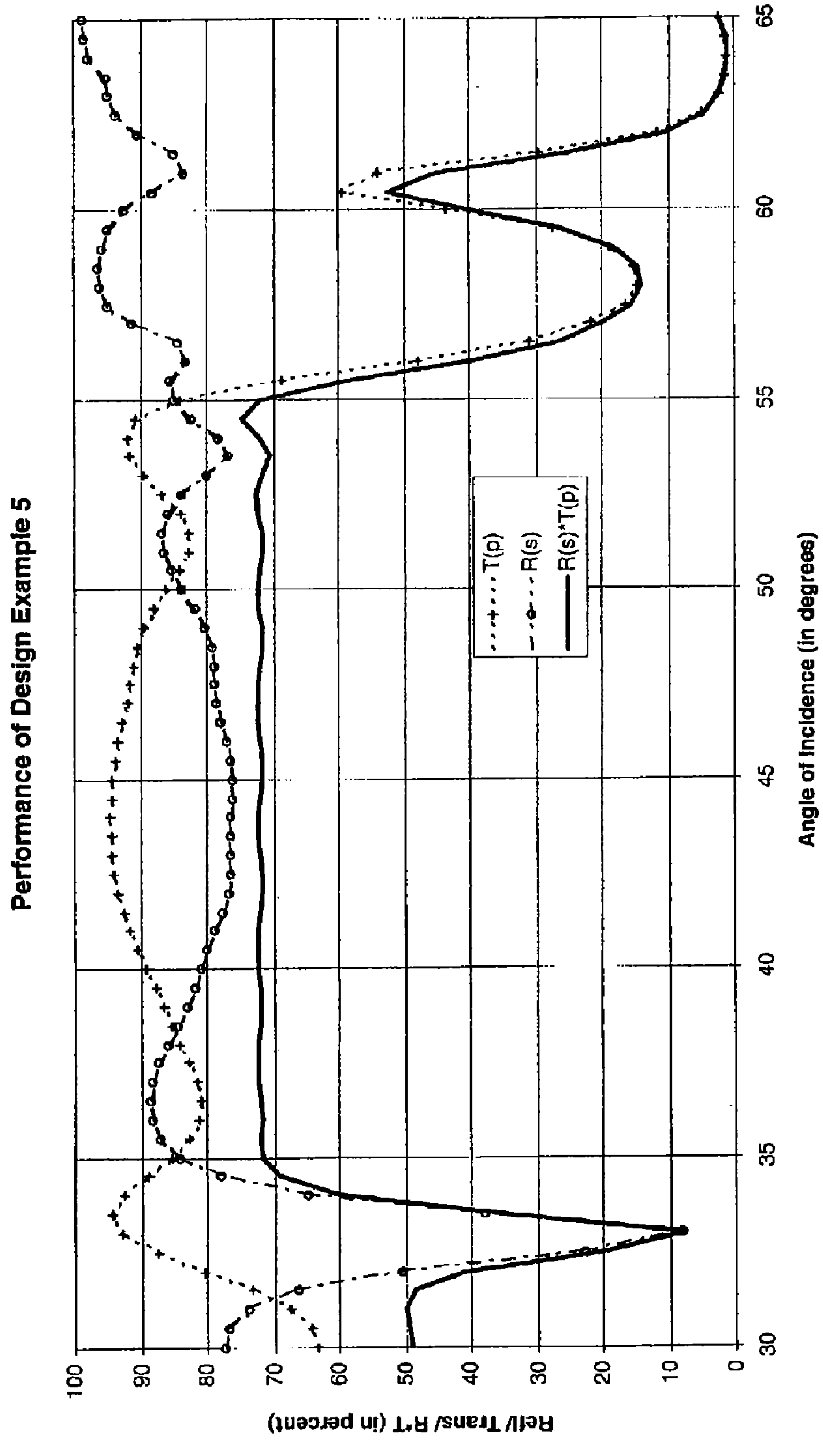

Performance of Design Example 5
Refl/ Trans/ R*T (in percent)
Angle of Incidence (in degrees)
T(p)
R(s)
R(s)*T(p)
0
10
20
30
40
50
60
70
80
90
100
30
35
40
45
50
55
60
65

FIG. 8

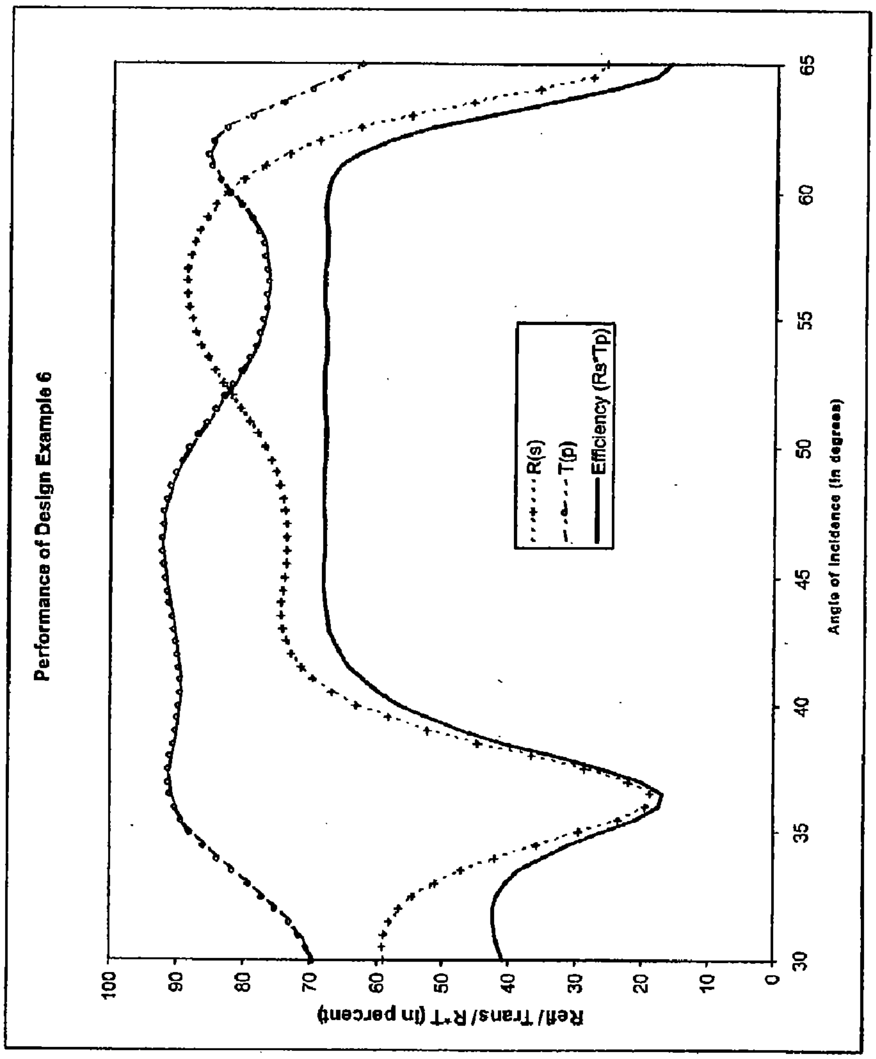

Performance of Design Example 6
R(s)
T(p)
Efficiency (Rs*Tp)
Refl/ Trans/ R*T (in percent)
Angle of Incidence (in degrees)
100
90
80
70
60
50
40
30
20
10
0
30
35
40
45
50
55
60
65

FIG. 9

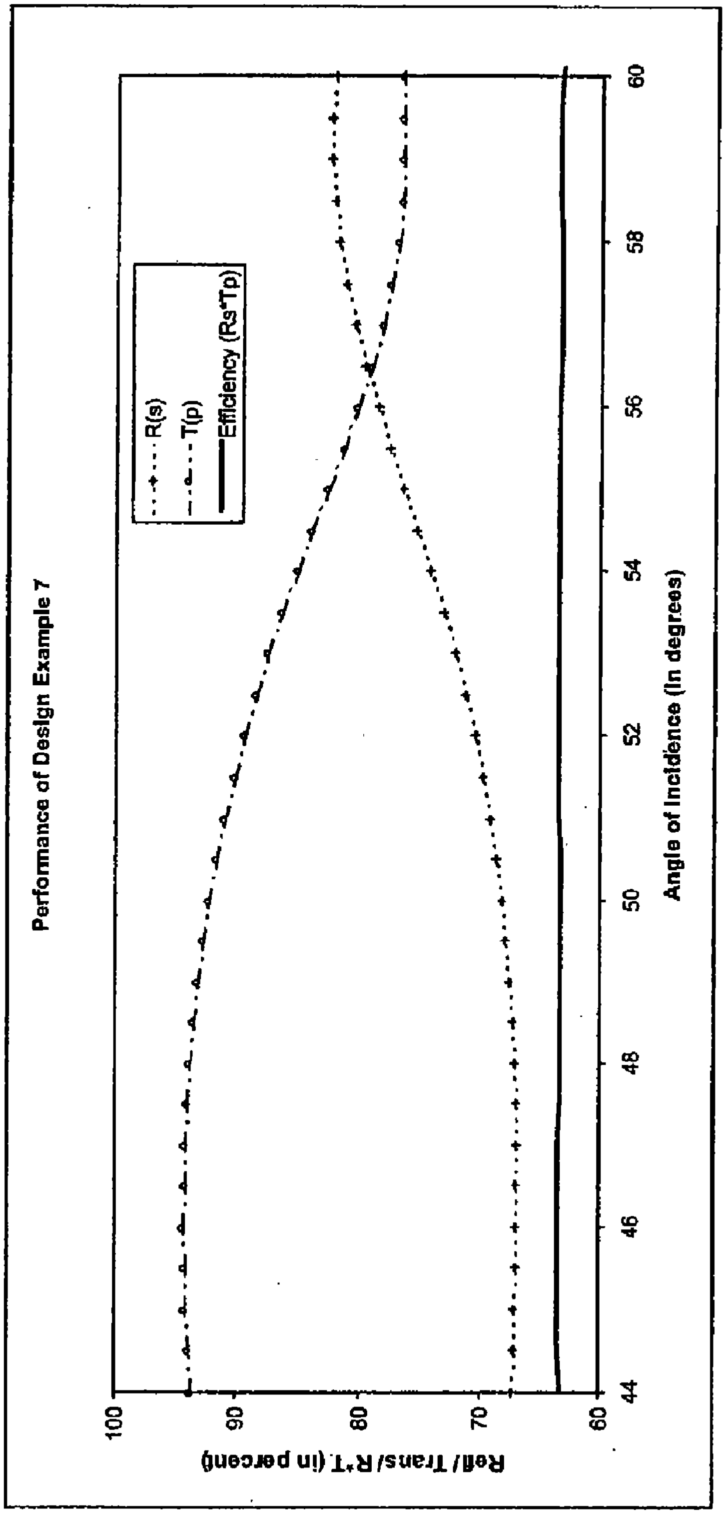

Performance of Design Example 7
R(s)
T(p)
Efficiency (Rs*Tp)
Refl/ Trans/ R*T (in percent)
100
90
80
70
60
44
46
48
50
52
54
56
58
60
Angle of Incidence (in degrees)

FIG. 10

ULTRAVIOLET POLARIZATION BEAM SPLITTER WITH MINIMUM APODIZATION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 10/458,629, filed on Jun. 11, 2003, now allowed, titled "Ultraviolet Polarization Beam", which is a is a continuation-in-part of U.S. patent application Ser. No. 10/264,318, filed Jan. 20, 2004, now U.S. Pat. No. 6,680,794, which is a continuation of U.S. patent application Ser. No. 09/538,529, filed Mar. 30, 2000, now U.S. Pat. No. 6,480,330, which is a non-provisional of U.S. Provisional Patent Application No. 60/184,782, filed Feb. 24, 2000, all of which are incorporated herein by reference in their entireties.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention pertains to optics, and in particular, to beam splitters used in microlithography.

[0004] 2. Related Art

[0005] Photolithography (also called microlithography) is a semiconductor fabrication technology. Photolithography uses ultraviolet or visible light to generate fine patterns in a semiconductor device design. Many types of semiconductor devices, such as, diodes, transistors, and integrated circuits, can be fabricated using photolithographic techniques. Exposure systems or tools are used to carry out photolithographic techniques, such as etching, in semiconductor fabrication. An exposure system can include a light source, reticle, optical reduction system, and a wafer alignment stage. An image of a semiconductor pattern is printed or fabricated on the reticle (also called a mask). A light source illuminates the reticle to generate an image of the particular reticle pattern. An optical reduction system is used to pass a high-quality image of the reticle pattern to a wafer. See, Nonogaki et al., *Microlithography Fundamentals in Semiconductor Devices and Fabrication Technology*, Marcel Dekker, Inc., New York, N.Y. (1998), incorporated in its entirety herein by reference.

[0006] Integrated circuit designs are becoming increasingly complex. The number of components and integration density of components in layouts is increasing. Demand for an ever-decreasing minimum feature size is high. The minimum feature size (also called line width) refers to the smallest dimension of a semiconductor feature that can be fabricated within acceptable tolerances. As a result, it is increasingly important that photolithographic systems and techniques provide a higher resolution.

[0007] One approach to improve resolution is to shorten the wavelength of light used in fabrication. Increasing the numerical aperture (NA) of the optical reduction system also improves resolution. Indeed, commercial exposure systems have been developed with decreasing wavelengths of light and increasing NA.

[0008] Catadioptric optical reduction systems include a mirror that reflects the imaging light after it passes through the reticle onto a wafer. A beam splitter cube is used in the optical path of the system. A conventional beam splitter cube, however, transmits about 50% of input light and reflects about 50% of the input light. Thus, depending upon the particular configuration of optical paths, significant light loss can occur at the beam splitter.

[0009] In UV photolithography, however, it is important to maintain a high light transmissivity through an optical reduction system with little or no loss. Exposure time and the overall semiconductor fabrication time depends upon the intensity or magnitude of light output onto the wafer. To reduce light loss at the beam splitter, a polarizing beam splitter and quarter-wave plates are used.

[0010] Generally, polarizing beam splitters are designed for maximum optical throughput, but without a particular attention to the apodization they impose on the pupil of the projection optics. In optical systems having low numerical apertures (i.e., on numerical apertures corresponding to a lower range of operating angles at the beam splitter coating), this is not a significant problem, since the natural bandwidth of the coating is typically large enough to cover the requirements. However, at higher numerical apertures, the coating designs become more complex, and result in an increase in undesirable performance fluctuations over the angular range of operation.

[0011] Accordingly, what is needed is a beamsplitter with a relatively flat apodization function over a wide angular range that is usable in UV photolithography.

SUMMARY OF THE INVENTION

[0012] The present invention embodies a technique for providing a beam splitter with a relatively flat apodization function.

[0013] In an embodiment of the present invention, a beam splitter is provided whose product of the P transmittance and S transmittance is relatively flat.

[0014] In another embodiment of the present invention, a beam splitter is provided having the above characteristics that is usable for ultraviolet and deep ultraviolet photo lithographic applications.

[0015] In one aspect of the invention, there is provided a beamsplitter including a first fluoride prism and a second fluoride prism. A coating interface is between the first and second fluoride prisms, wherein an overall $R(s)*T(p)$ function of the beamsplitter varies no more than ±2.74% in the range of 40-50 degrees of incidence.

[0016] Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

[0017] To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, there is provided a

BRIEF DESCRIPTION OF THE FIGURES

[0018] The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate the present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention. In the drawings:

[0019] FIG. **1**A is a perspective view of a conventional polarizing beam splitter cube;

[0020] FIG. **1**B is a diagram showing a cross-section of a conventional coating interface for the polarizing beam splitter cube of FIG. **1**A;

[0021] FIG. **2**A illustrates how the polarizing beam splitter cube of FIG. **1**A separates light into separate polarization states;

[0022] FIG. **2**B illustrates how the polarizing beam splitter cube of FIG. **1**A can be used as part of a catadioptric optical reduction system to improve transmission efficiency;

[0023] FIG. **3**A is a perspective view of a UV polarizing beam splitter cube according to one embodiment of the present invention;

[0024] FIG. **3**B is a diagram showing a cross-section of a coating interface for the UV polarizing beam splitter cube of FIG. **3**A; and

[0025] FIGS. **4-10** illustrate exemplary beamsplitter transmission performance according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] The present invention will now be described with reference to the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

[0027] While the present invention is described herein with reference to illustrative embodiments for particular applications, it should be understood that the invention is not limited thereto. Those skilled in the art with access to the teachings provided herein will recognize additional modifications, applications, and embodiments within the scope thereof and additional fields in which the present invention would be of significant utility.

Terminology

[0028] The terms "beam splitter" or "cube" used with respect to the present invention have a broad meaning that refers to a beam splitter that includes, but is not limited to, a beam splitter having an overall cubic shape, rectangular cubic shape, or truncated cubic shape, or approximating an overall cubic shape, rectangular cubic shape, or truncated cubic shape.

[0029] The term "long conjugate end" refers to a plane at the object or reticle end of an optical reduction system.

[0030] The term "short conjugate end" refers to the plane at the image or wafer end of an optical reduction system.

[0031] The term "wafer" refers to the base material in semiconductor manufacturing, which goes through a series of photomasking, etching and/or implementation steps.

[0032] The term "wave plate" refers to retardation plates or phase shifters made from materials which exhibit birefringence.

[0033] FIGS. **1**A and **1**B illustrate an example conventional polarizing beam splitter cube **100** used in a conventional catadioptric optical reduction system. Polarizing beam splitter cuber **100** includes two prisms **110**, **150**, and a coating interface **120**. Prisms **120**, **150** are made of fused silica and are transmissive at wavelengths of 248 nm and 193 nm. Coating interface **120** is a multi-layer stack. The multi-layer stack includes alternating thin film layers. The alternating thin film layers are made of thin films having relatively high and low indices of refraction (n_1 and n_2). The alternating thin film layers and their respective indices of refraction are selected such that the MacNeille condition (also called Brewster condition) is satisfied. In one example, the high index of refraction thin film material is an aluminum oxide. The low index of refraction material is aluminum fluoride. A protective layer may be added during the fabrication of the stack. Cement or glue is included to attach one of the alternating layers to a prism **150** at face **152** or to attach the protective layer to prism **110** at face **112**. As shown in FIG. **2**A, the MacNeille condition (as described in U.S. Pat. No. 2,403,731) is a condition at which light **200** incident upon the multi-layer stack is separated into two beams **260**, **280** having different polarization states. For example, output beam **260** is an S-polarized beam, and output beam **280** is a P-polarized beam (or polarized at 90 degrees with respect to each other). FIG. **2**B shows the advantage of using a polarizing beam splitter in a catadioptric optical reduction system to minimize light loss. Incident light **200** (usually having S and P polarization states) passes through a quarter-wave plate **210**. Quarter wave plate **210** converts all of incident light **200** to a linearly polarized beam in an S polarization state. Beam splitter cube **100** reflects all or nearly all of the S polarization to quarter wave plate **220** and mirror **225**. Quarter wave plate **220** when doubled passed acts like a half-waveplate. Quarter wave plate **220** converts the S polarization light to circular polarization, and after reflection from mirror **225**, converts light into P-polarized light. The P-polarized light is transmitted by beam splitter cube **100** and output as a P-polarized beam **290** toward the wafer. In this way, the polarizing beam splitter **100** and quarter wave plates **210**, **220** avoid light loss in a catadioptric optical reduction system that includes a mirror **225**. Note, as an alternative, mirror **225** and quarter wave plate **220** can be positioned at face B of cube **100**, rather than at face A, and still achieve the same complete or nearly complete light transmission over a compact optical path length.

[0034] The invention, which will be further described below, can be used in catadioptric photolithography systems. It can be used in any polarizing beamsplitter system in which the beamsplitter is used over a range of angles and in which the light passes through the beamsplitter twice at orthogonal polarizations.

[0035] Typical polarizing beamsplitters, as described above with reference to FIGS. **1**A-**2**B, are designed for maximum optical throughput but without particular attention to the apodization they impose on the pupil of the projection optics. This is not a significant problem in systems with low numerical apertures (i.e., a lower range of operating angles at the beamsplitter coating), where the natural bandwidth of the coating was large enough to cover the requirement. At higher numerical apertures, coating designs become more complex, with a resultant increase in undesirable performance fluctuations over the angular range of operation.

[0036] In the beamsplitter of the present invention, light passes through the beamsplitter twice, first in S polarization and then again in P polarization. The two performance curves (S and P as functions of angle) multiplied together determine the overall apodization function that the coating introduces into the system pupil. Previous efforts to design coatings with lower pupil apodization focused on flattening the S and P performance curves individually. In the design of the beamsplitter coating it is relatively easy to effect changes in the performance for the S polarization, and more difficult to effect changes in the P polarization performance. If the beamsplitter is doubled-passed in the system, P polarization performance variations can be compensated for by a coating whose S polarization performance has the opposite "signature." When the two functions R(s) and T(p) are multiplied together, they produce an apodization function R(s)*T(p) that is relatively flat.

[0037] To achieve a relatively flat R(s)*T(p) function, the present invention provides a ultraviolet (UV) polarizing beam splitter. The UV polarizing beam splitter is transmissive to light at wavelengths equal to or less than 200 nm, for example, at 193 nm or 157 nm. The UV polarizing beam splitter can image at high quality light incident over a wide range of reflectance and transmittance angles. The UV polarizing beam splitter can accommodate divergent light in an optical reduction system having a numeric aperture at a wafer plane greater than 0.6, and for example at 0.75. In different embodiments, the UV polarizing beam splitter can have a cubic, rectangular cubic, or truncated cubic shape, or approximates a cubic, rectangular cubic, or truncated cubic shape.

[0038] In one embodiment, a UV polarizing beam splitter cube comprises a pair of prisms and a coating interface. The prisms are made of at least a fluoride material, such as, calcium fluoride (CaF_2) or barium fluoride (BaF_2). The coating interface has a plurality of layers of a thin film fluoride material. In one example implementation, the coating interface includes a multi-layer stack of alternating layers of thin film fluoride materials. The alternating layers of thin film fluoride materials comprise first and second fluoride materials. The first and second fluoride materials have respective first and second refractive indices. The first refractive index is greater than (or higher than) the second refractive index. In one feature of the present invention, the first and second refractive indices form a stack of fluoride materials having relatively high and low refractive indices of refraction such that the coating interface separates UV light (including light at wavelengths less than 200 nm, for example, at 193 nm or 157 nm) depending on two polarized states.

[0039] In one example, to achieve a relatively flat R(s)*T(p) function, the coating interface comprises a multi-layer design of the form $(H\ L)^n\ H$ or $(H\ L)^n$, where H indicates a layer of a first fluoride material having a relatively high refractive index. The first fluoride material can include, but is not limited to, gadolinium tri-fluoride (GdF_3), lanthanum tri-fluoride (LaF_3), samarium fluoride (SmF_3), europium fluoride (EuF_3), terbium fluoride (TbF_3), dysprosium fluoride (DyF_3), holmium fluoride (HoF_3), erbium fluoride (ErF_3), thulium fluoride (TmF_3), ytterbium fluoride (YbF_3), lutetium fluoride (LuF_3), zirconium fluoride (ZrF_4), hafnium fluoride (HfF_4), yttrium fluoride (YF_3), neodymium fluoride (NdF_3), any of the other lanthanide series tri-fluorides, metallic fluorides, or other high index, ultraviolet transparent material. L indicates a layer of a second fluoride material having a relatively low refractive index. The second fluoride material can include, but is not limited to, magnesium fluoride (MgF_2), aluminum tri-fluoride (AlF_3), barium fluoride (BaF_2), strontium fluoride (SrF_2), calcium fluoride (CaF_2), lithium fluoride (LiF), and sodium fluoride (NaF), or other low index, ultraviolet transparent material. The value "n" indicates the basic (H L) group is repeated n times in a multi-layer stack, where n is a whole number equal to one or more.

[0040] According to a further feature, the prisms and coating interface are joined by optical contact. No cement is needed, although its use is not precluded.

[0041] Further multi-layer designs can be generated by computer iterated design. Layers in a multi-layer stack can also be graded across the hypotenuse face of a prism to adjust layer thicknesses at any point so as to compensate for changes in the incidence angle of the light.

[0042] The present invention provides a method for splitting an incident light beam based on polarization state. The method includes the step of orienting a coating interface having a plurality of layers of a fluoride material at an angle relative to the incident light such that the coating interface transmits incident light in a first polarization state and reflects incident light in a second polarization state. In one example, the method further includes the step of selecting thicknesses of alternating thin film layers and their respective indices of refraction such that the coating interface transmits incident light at a wavelength equal to or less than 200 nm in a first polarization state and reflects incident light at a wavelength equal to or less than 200 nm in a second polarization state.

UV Polarizing Beam Splitter

[0043] FIG. **3**A is a perspective view of a UV polarizing beam splitter cube **300** according to one embodiment of the present invention. UV polarizing beam splitter cube **300** has a pair of prisms **310**, **350** and a coating interface **320**. Prisms **310**, **350** are preferably made of a fluoride material. Coating interface **320** has a plurality of layers of a thin film fluoride material.

In the example shown in FIG. **3**A, prism **310** is a right angle prism having five faces. These five faces consist of two side faces, two end faces, and a hypotenuse face. The two side faces are square (or approximately square) at their perimeter and share right angle corners **314** and **316**. One side face B is shown in FIG. **3**A, the other side face is not shown. The two end faces are both right triangles. One end face A, shown in FIG. **3**A, is a right triangle at its perimeter formed by a ninety degree (or approximately ninety degree) angle at corner **314** and two 45 degree (or approximately 45 degree) angles opposite corner **314**. The other end face (not shown) is the right triangle formed by a ninety degree (or approximately ninety degree) angle at corner **316** and two 45 degree (or approximately 45 degree) angles opposite corner **316**. The hypotenuse face is a planar face **312** which is on a hypotenuse side of right angle prism **310** opposite right angle corners **314**, **316**. Prism **350** is also a right angle prism having five faces. These five faces consist of two side faces, two end faces, and a hypotenuse face. The two side faces are square (or approximately square) at their perimeter and share right angle corners **354** and **356**. One side face D is shown in FIG. **3**A, the other side face is not shown. The two end faces are both right triangles. One end face C, shown in FIG. **3**A, is a right triangle at its perimeter formed by a ninety degree (or approximately ninety degree) angle at corner **354** and two 45 degree (or approximately 45 degree) angles opposite corner **354**. The other end face (not shown) is the right triangle formed by a ninety degree (or approximately ninety degree) angle at corner **356** and two 45 degree (or approximately 45 degree) angles opposite corner **356**. The hypotenuse face is a planar face **352** which is on a hypotenuse side of right angle prism **350** opposite right angle corners **354**, **356**. Coating interface **320** lies between hypotenuse faces **312** and **352**. UV polarizing beam splitter cube **300** has width, depth, and height dimensions equal to values d**1**, d**2**, and d**3** respectively, as shown in FIG. **3**A. In one example implementation, d**1**, d**2**, and d3 are equal (or approximately equal) such that prisms **310** and **350** when coupled along their faces **312** and **352** have an overall cube or cube-like shape. In one example implementation, prisms **310**, **350** are made of calcium fluoride (CaF2) material, barium fluoride (BaF2) material, or a combination thereof.

Coating Interface

[0044] FIG. 3B is a diagram showing a cross-section of an example coating interface **320**, used to achieve a relatively flat R(s)*T(p) function, in greater detail. Coating interface **320** includes a stack of alternating layers of thin film fluoride materials (**331**-**337**, **341**-**346**), and a protective layer **351**. Anti-reflection (AR) coatings (not shown) can also be included in coating interface **320**. Protective layer **351** and AR coatings are optional. Also, the present invention in not limited to thirteen layers of alternating layers of thin film fluoride materials. In general, larger and smaller numbers of alternating layers of thin film fluoride materials can be used as would be apparent to a person skilled in the art given this description. Further, FIG. 3B shows the coating interface **320** mounted on face **352** of prism **350**. The stack of alternating layers of thin film fluoride materials (**331**-**337**, **341**-**346**) and/or protective layer **351** are grown, etched, or fabricated on face **352** using conventional thin film techniques. Prism **310** is then placed in optical contact with the coating interface **320**. In this way, prisms **310** and **350** are coupled strongly through coating interface **320** resulting in a very strong polarizing beam splitter cube. One further feature of the present invention is that it applies this optical contact (where optical components are joined so closely together that van der Waal's forces couple the components to one another) in a complex geometry involving angled surfaces, such as, the hypotenuse face of prism **310**. The alternating layers of thin film fluoride materials include two groups of layers. The first group of layers **331**-**337** has a first index of refraction n_1. The second group of layers **341**-**346** has a second index of refraction n_2. According to one feature of the present invention, the first and second refractive indices n_1 and n_2 are different. In particular, the second refractive index n_2 is relatively low compared to the first refractive index n_1. In this way, coating interface **320** includes a stack of fluoride materials **331**-**337**, **341**-**346** having alternating relatively high and low refractive indices n_1, n_2 such that the coating interface **320** separates incident UV light based on two different polarization states, such as S and P polarization states. According to the present invention, polarizing beam splitter cube **300** can be used with light at wavelengths equal to or less than 200 nm, and in particular, at 193 or 157.6 nm, for example.

[0045] As noted above, to achieve a relatively flat R(s)*T(p) function, the coating interface **320** comprises a multilayer design of the form $(H\,L)^n\,H$ or $(H\,L)^n$, where H indicates a layer of a first fluoride material having relatively high refractive index. The first fluoride material can include, but is not limited to, gadolinium tri-fluoride (GdF_3), lanthanum tri-fluoride (LaF_3), samarium fluoride (SmF_3), europium fluoride (EuF_3), terbium fluoride (TbF_3), dysprosium fluoride (DyF_3), holmium fluoride (HoF_3), erbium fluoride (ErF_3), thulium fluoride (TmF_3), ytterbium fluoride (YbF_3), lutetium fluoride (LuF_3), zirconium fluoride (ZrF_4), hafnium fluoride (HfF_4), yttrium fluoride (YF_3), neodymium fluoride (NdF_3), any of the other lanthanide series tri-fluorides, metallic fluorides, or other high index, ultraviolet-transparent material. L indicates a layer of a second fluoride material having relatively low refractive index. The second fluoride material can include, but is not limited to, magnesium fluoride (MgF_2), aluminum tri-fluoride (AlF_3), barium fluoride (BaF_2), strontium fluoride (SrF_2), calcium fluoride (CaF_2), lithium fluoride (LiF), and sodium fluoride (NaF), or other low index, ultraviolet transparent material. The superscript value "n" indicates the basic (H L) group is repeated n times in a multi-layer stack, where n is a whole number equal to one or more.

[0046] Other designs for a multi-layer coating interface **320**, **520** can be generated through a computer iterated technique as would be apparent to a person skilled in the art given this description.

[0047] The examples below are illustrative of how a flat overall R(s)*T(p) function can be achieved using a number of alternating coating layers.

Beamsplitter Example 1

[0048] The table below illustrates one example of a coating interface **320** for 157.6 μm that satisfies the requirements of a flat R(s)*T(p) apodization function using a total of 27 alternating layers (n=13) of MgF_2 and LaF_3. This example provides a relatively flat R(s)*T(p) function between 35 and 55 degrees incident. In that range, the R(s)*T(p) function ranges from a maximum of 70.85 to a minimum of 65.37, or a delta of 5.48% (±2.74%).

TABLE 1

Layer Number	Material	Mechanical Thickness (nm)	Layer Index (at 157.6 nm)	Optical Thickness (quarter-waves at 157.6 nm)
exit medium	CaF_2	massive		
1	MgF_2	37.14	1.465	1.381
2	LaF_3	9.18	1.78	0.415
3	MgF_2	36.58	1.465	1.360
4	LaF_3	16.11	1.78	0.728
5	MgF_2	45.68	1.465	1.699
6	LaF_3	8.92	1.78	0.403
7	MgF_2	42.92	1.465	1.596
8	LaF_3	22.20	1.78	1.003
9	MgF_2	32.03	1.465	1.191
10	LaF_3	19.82	1.78	0.895
11	MgF_2	30.10	1.465	1.119
12	LaF_3	24.30	1.78	1.098
13	MgF_2	31.56	1.465	1.173
14	LaF_3	25.91	1.78	1.171
15	MgF_2	30.78	1.465	1.144
16	LaF_3	24.27	1.78	1.096
17	MgF_2	28.51	1.465	1.060
18	LaF_3	23.46	1.78	1.060
19	MgF_2	31.52	1.465	1.172
20	LaF_3	27.37	1.78	1.237
21	MgF_2	35.97	1.465	1.337
22	LaF_3	29.89	1.78	1.350
23	MgF_2	39.21	1.465	1.458
24	LaF_3	30.97	1.78	1.399
25	MgF_2	42.48	1.465	1.580
26	LaF_3	30.31	1.78	1.369
27	MgF_2	31.33	1.465	1.165
entrance medium	CaF_2	massive		

The R(s), T(p) and the overall R(s)*T(p) functions are shown in FIG. **4** in graphical form, and are illustrated in the Table 2 below in tabular form:

TABLE 2

Wavelength 157.6 nm
Range 35-55 degrees
Substrate CaF_2
H LaF_3
L MgF_2

angle	T(p)	R(s)	R(s) * T(p)
30.0	41.67	84.81	35.34
30.5	44.75	84.78	37.94
31.0	47.94	84.93	40.71
31.5	51.23	85.21	43.65
32.0	54.62	85.60	46.75
32.5	58.10	86.03	49.98
33.0	61.66	86.45	53.30
33.5	65.24	86.79	56.62
34.0	68.77	87.02	59.84
34.5	72.13	87.08	62.82
35.0	75.18	86.96	65.37
35.5	77.77	86.60	67.35
36.0	79.83	85.98	68.64
36.5	81.33	85.07	69.19
37.0	82.35	83.89	69.08
37.5	83.00	82.48	68.46
38.0	83.45	81.02	67.60
38.5	83.85	79.72	66.84
39.0	84.33	78.83	66.47
39.5	84.94	78.47	66.65
40.0	85.72	78.57	67.35
40.5	86.61	78.91	68.35
41.0	87.57	79.25	69.39
41.5	88.51	79.38	70.26
42.0	89.37	79.19	70.78
42.5	90.11	78.63	70.85
43.0	90.71	77.69	70.48
43.5	91.18	76.49	69.74
44.0	91.52	75.23	68.85
44.5	91.77	74.19	68.08
45.0	91.94	73.68	67.74
45.5	92.05	73.80	67.93
46.0	92.10	74.42	68.54
46.5	92.09	75.26	69.31
47.0	92.00	76.02	69.94
47.5	91.82	76.49	70.23
48.0	91.51	76.59	70.09
48.5	91.07	76.34	69.52
49.0	90.47	75.85	68.63
49.5	89.77	75.35	67.64
50.0	89.02	75.10	66.85
50.5	88.30	75.29	66.48
51.0	87.70	75.94	66.60
51.5	87.27	76.86	67.08
52.0	87.00	77.80	67.69
52.5	86.84	78.53	68.19
53.0	86.72	78.88	68.40
53.5	86.59	78.81	68.24
54.0	86.48	78.31	67.72
54.5	86.48	77.43	66.96
55.0	86.72	76.24	66.11
55.5	87.29	74.80	65.30
56.0	88.13	73.13	64.45
56.5	88.95	71.10	63.24
57.0	89.26	68.38	61.04
57.5	88.54	64.44	57.06
58.0	86.61	58.46	50.63
58.5	83.78	49.39	41.38
59.0	80.81	36.52	29.52
59.5	78.60	21.85	17.17
60.0	77.82	13.52	10.52
60.5	78.79	19.28	15.19
61.0	81.31	33.46	27.20
61.5	84.46	46.33	39.13

TABLE 2-continued

Wavelength 157.6 nm
Range 35-55 degrees
Substrate CaF_2
H LaF_3
L MgF_2

angle	T(p)	R(s)	R(s) * T(p)
62.0	86.54	54.54	47.19
62.5	85.76	58.28	49.98
63.0	81.71	58.10	47.47
63.5	75.84	53.92	40.90
64.0	70.32	44.86	31.55
64.5	66.72	29.85	19.92
65.0	65.78	11.20	7.37

Beamsplitter Example 2

[0049] Table 3 below illustrates another example of a coating interface **320** for 157.6 n_1 that satisfies the requirements of a flat R(s)*T(p) apodization function using a total of 29 alternating layers (n=14) of MgF_2 and LaF_3. This example provides a relatively flat R(s)*T(p) function between 35 and 55 degrees incident. In that range, the R(s)*T(p) function ranges from a maximum of 67.9% to a minimum of 66.15%, or a delta of 1.74% (±0.87%).

TABLE 3

Layer Number	Material	Mechanical Thickness (nm)	Layer Index (at 157.6 nm)	Optical Thickness (quarter-waves at 157.6 nm)
exit medium	CaF_2	massive		
1	MgF_2	36.50	1.465	1.357
2	LaF_3	7.94	1.78	0.359
3	MgF_2	36.32	1.465	1.350
4	LaF_3	16.76	1.78	0.757
5	MgF_2	38.91	1.465	1.447
6	LaF3	14.25	1.78	0.644
7	MgF2	34.13	1.465	1.269
8	LaF3	22.09	1.78	0.998
9	MgF2	32.09	1.465	1.193
10	LaF3	23.17	1.78	1.047
11	MgF2	29.18	1.465	1.085
12	LaF3	22.79	1.78	1.030
13	MgF2	29.33	1.465	1.091
14	LaF3	24.78	1.78	1.120
15	MgF2	30.99	1.465	1.152
16	LaF3	25.57	1.78	1.155
17	MgF2	30.99	1.465	1.152
18	LaF3	23.80	1.78	1.075
19	MgF2	29.45	1.465	1.095
20	LaF3	21.68	1.78	0.979
21	MgF2	32.53	1.465	1.210
22	LaF3	25.53	1.78	1.153
23	MgF2	39.95	1.465	1.485
24	LaF3	29.40	1.78	1.328
25	MgF2	44.37	1.465	1.650
26	LaF3	28.78	1.78	1.300
27	MgF2	41.05	1.465	1.526
28	LaF3	25.76	1.78	1.164
29	MgF2	24.85	1.465	0.924
entrance medium	CaF_2	massive		

The R(s), T(p) and the overall R(s)*T(p) functions are shown in FIG. **5** in graphical form, and are illustrated in the Table 2 below in tabular form:

TABLE 4

Wavelength 157.6 nm
Range 35-55 degrees
Substrate CaF_2
H LaF_3
L MgF_2

angle	T(p)	R(s)	R(s) * T(p)
30.0	47.96	82.40	39.52
30.5	51.50	82.73	42.61
31.0	54.89	83.39	45.77
31.5	58.15	84.21	48.97
32.0	61.31	85.06	52.15
32.5	64.38	85.83	55.26
33.0	67.36	86.45	58.23
33.5	70.17	86.85	60.95
34.0	72.73	87.03	63.30
34.5	74.94	86.96	65.17
35.0	76.75	86.63	66.49
35.5	78.15	86.05	67.25
36.0	79.21	85.22	67.50
36.5	80.02	84.20	67.38
37.0	80.73	83.06	67.05
37.5	81.43	81.93	66.71
38.0	82.21	80.90	66.51
38.5	83.10	80.07	66.53
39.0	84.08	79.40	66.77
39.5	85.13	78.84	67.11
40.0	86.16	78.26	67.43
40.5	87.13	77.58	67.59
41.0	87.99	76.74	67.52
41.5	88.71	75.77	67.22
42.0	89.31	74.77	66.78
42.5	89.80	73.90	66.36
43.0	90.22	73.32	66.15
43.5	90.57	73.14	66.24
44.0	90.88	73.30	66.61
44.5	91.15	73.65	67.13
45.0	91.39	73.99	67.61
45.5	91.57	74.15	67.90
46.0	91.67	74.06	67.89
46.5	91.68	73.72	67.58
47.0	91.58	73.24	67.07
47.5	91.37	72.82	66.53
48.0	91.07	72.67	66.18
48.5	90.71	72.93	66.15
49.0	90.32	73.60	66.47
49.5	89.91	74.50	66.99
50.0	89.49	75.42	67.49
50.5	89.02	76.16	67.80
51.0	88.46	76.65	67.81
51.5	87.83	76.87	67.51
52.0	87.18	76.88	67.02
52.5	86.62	76.78	66.51
53.0	86.34	76.66	66.19
53.5	86.44	76.53	66.15
54.0	86.97	76.28	66.35
54.5	87.83	75.74	66.52
55.0	88.73	74.63	66.22
55.5	89.32	72.61	64.85
56.0	89.26	69.21	61.78
56.5	88.48	63.81	56.46
57.0	87.19	55.64	48.51
57.5	85.85	44.32	38.05
58.0	84.93	31.55	26.79
58.5	84.71	22.80	19.32
59.0	85.20	23.04	19.63
59.5	86.12	29.65	25.53
60.0	86.96	36.61	31.84
60.5	87.25	40.65	35.46
61.0	86.82	40.89	35.50
61.5	85.90	37.21	31.97
62.0	84.99	29.67	25.21
62.5	84.49	19.04	16.09
63.0	84.52	8.16	6.90
63.5	84.74	1.86	1.58
64.0	84.60	2.87	2.43
64.5	83.62	8.46	7.07
65.0	81.86	13.91	11.38

Beamsplitter Example 3

[0050] Table 5 below illustrates another example of a coating interface **320** that satisfies the requirements of a flat R(s)*T(p) apodization function using a total of 26 alternating layers (n=13) of MgF_2 and LaF_3. This example provides a relatively flat R(s)*T(p) function between 40 and 60 degrees incident. In that range, the R(s)*T(p) function ranges from a maximum of 72.69% to a minimum of 71.80%, or a delta of 0.89% (±0.445%).

TABLE 5

Layer Number	Material	Mechanical Thickness (nm)	Layer Index (at 157.6 nm)	Optical Thickness (quarter-waves at 157.6 nm)
exit medium	CaF_2	massive		
1	MgF_2	38.09	1.465	1.416
2	LaF_3	8.56	1.78	0.387
3	MgF_2	40.19	1.465	1.494
4	LaF_3	25.39	1.78	1.147
5	MgF_2	25.43	1.465	0.946
6	LaF_3	20.00	1.78	0.904
7	MgF_2	29.25	1.465	1.088
8	LaF_3	27.49	1.78	1.242
9	MgF_2	36.72	1.465	1.365
10	LaF_3	16.23	1.78	0.733
11	MgF_2	27.28	1.465	1.014
12	LaF_3	29.49	1.78	1.332
13	MgF_2	120.76	1.465	4.490
14	LaF_3	30.60	1.78	1.382
15	MgF_2	38.55	1.465	1.433
16	LaF_3	30.80	1.78	1.391
17	MgF_2	39.70	1.465	1.476
18	LaF_3	31.34	1.78	1.416
19	MgF_2	40.71	1.465	1.514
20	LaF_3	30.44	1.78	1.375
21	MgF_2	45.04	1.465	1.675
22	LaF_3	21.30	1.78	0.962
23	MgF_2	23.64	1.465	0.879
24	LaF_3	8.82	1.78	0.398
25	MgF_2	51.75	1.465	1.924
26	LaF_3	25.88	1.78	1.169
entrance medium	CaF_2	massive		

The R(s), T(p) and the overall R(s)*T(p) functions are shown in FIG. **6** in graphical form, and are illustrated in the Table 2 below in tabular form:

TABLE 6

Wavelength 157.6 nm Range 40-60 degrees Substrate CaF_2 H LaF_3 L MgF_2			
angle	T(p)	R(s)	R(s) * T(p)
30.0	63.71	69.28	44.14
30.5	62.12	72.74	45.19
31.0	61.84	74.61	46.14
31.5	62.88	75.10	47.22
32.0	65.23	74.22	48.41
32.5	68.80	71.69	49.32
33.0	73.37	66.88	49.07
33.5	78.53	58.54	45.97
34.0	83.64	44.72	37.40
34.5	87.91	24.45	21.50
35.0	90.68	6.05	5.48
35.5	91.68	9.93	9.11
36.0	91.12	32.89	29.97
36.5	89.56	53.91	48.29
37.0	87.66	67.30	59.00
37.5	85.91	75.18	64.59
38.0	84.62	79.80	67.53
38.5	83.91	82.50	69.23
39.0	83.75	84.01	70.36
39.5	84.04	84.70	71.18
40.0	84.62	84.82	71.78
40.5	85.36	84.49	72.12
41.0	86.15	83.84	72.22
41.5	86.92	82.99	72.13
42.0	87.65	82.09	71.95
42.5	88.35	81.28	71.81
43.0	89.01	80.67	71.80
43.5	89.64	80.23	71.92
44.0	90.21	79.90	72.08
44.5	90.69	79.59	72.18
45.0	91.07	79.25	72.17
45.5	91.33	78.91	72.07
46.0	91.46	78.64	71.93
46.5	91.47	78.53	71.83
47.0	91.37	78.64	71.85
47.5	91.15	78.96	71.97
48.0	90.79	79.43	72.12
48.5	90.28	79.97	72.20
49.0	89.59	80.54	72.16
49.5	88.69	81.18	72.00
50.0	87.58	82.02	71.83
50.5	86.30	83.16	71.76
51.0	84.91	84.60	71.83
51.5	83.52	86.18	71.98
52.0	82.24	87.69	72.12
52.5	81.15	88.96	72.19
53.0	80.28	89.92	72.19
53.5	79.63	90.57	72.13
54.0	79.19	90.94	72.02
54.5	78.97	91.05	71.90
55.0	78.99	90.93	71.83
55.5	79.29	90.61	71.84
56.0	79.86	90.10	71.95
56.5	80.62	89.44	72.10
57.0	81.40	88.66	72.17
57.5	82.07	87.80	72.05
58.0	82.68	86.89	71.83
58.5	83.52	85.95	71.78
59.0	84.91	84.98	72.15
59.5	86.63	83.91	72.69
60.0	87.12	82.49	71.87
60.5	83.25	80.23	66.79
61.0	72.90	76.04	55.43
61.5	58.52	67.52	39.51
62.0	45.05	48.70	21.94
62.5	35.16	13.70	4.82
63.0	29.00	16.06	4.66
63.5	25.91	58.38	15.12
64.0	25.40	78.80	20.01
64.5	27.46	86.76	23.82
65.0	32.39	90.12	29.19

Beamsplitter Example 4

[0051] Table 7 below illustrates another example of a coating interface **320** that satisfies the requirements of a flat R(s)*T(p) apodization function using a total of 32 alternating layers (n=16) of AlF_3 and NdF_3. This example provides a relatively flat R(s)*T(p) function between 35 and 55 degrees incident. In that range, the R(s)*T(p) function ranges from a maximum of 72.55% to a minimum 71.24%, or a delta of 1.31% (10.655%).

TABLE 7

Layer Number	Material	Mechanical Thickness (nm)	Layer Index (at 157.6 nm)	Optical Thickness (quarter-waves at 193 nm)
exit medium	CaF_2	massive		
1	NdF_3	28.95	1.7	1.0200
2	AlF_3	39.10	1.417	1.1483
3	NdF_3	24.88	1.7	0.8766
4	AlF_3	39.09	1.417	1.1480
5	NdF_3	28.67	1.7	1.0101
6	AlF_3	38.99	1.417	1.1451
7	NdF_3	23.93	1.7	0.8431
8	AlF_3	35.48	1.417	1.0420
9	NdF_3	28.67	1.7	1.0101
10	AlF_3	44.86	1.417	1.3174
11	NdF_3	35.18	1.7	1.2395
12	AlF_3	46.91	1.417	1.3776
13	NdF_3	36.51	1.7	1.2864
14	AlF_3	48.21	1.417	1.4158
15	NdF_3	37.64	1.7	1.3262
16	AlF_3	50.12	1.417	1.4719
17	NdF_3	38.90	1.7	1.3706
18	AlF_3	53.67	1.417	1.5762
19	NdF_3	41.69	1.7	1.4689
20	AlF_3	95.59	1.417	2.8073
21	NdF_3	48.10	1.7	1.6947
22	AlF_3	55.92	1.417	1.6423
23	NdF_3	40.70	1.7	1.4340
24	AlF_3	126.79	1.417	3.7236
25	NdF_3	30.49	1.7	1.0743
26	AlF_3	46.76	1.417	1.3732
27	NdF_3	23.50	1.7	0.8280
28	AlF_3	42.27	1.417	1.2414
29	NdF_3	26.20	1.7	0.9231
30	AlF_3	42.51	1.417	1.2484
31	NdF_3	17.93	1.7	0.6317
32	AlF_3	140.21	1.417	4.1177
entrance medium	CaF_2	massive		

The R(s), T(p) and the overall R(s)*T(p) functions are shown in FIG. **7** in graphical form, and are illustrated in the Table 8 below in tabular form:

TABLE 8

Wavelength 193 nm
Range 35-55 degrees
Substrate CaF_2
H NdF_3
L AlF_3

angle	T(p)	R(s)	R(s) * T(p)
30.0	44.49	89.57	39.85
30.5	45.29	89.66	40.60
31.0	48.52	88.81	43.08
31.5	54.32	86.62	47.06
32.0	62.78	81.91	51.42
32.5	73.33	71.24	52.24
33.0	84.11	44.86	37.73
33.5	92.02	2.27	2.09
34.0	94.70	29.38	27.83
34.5	92.54	66.24	61.30
35.0	88.02	81.04	71.33
35.5	83.48	87.12	72.73
36.0	80.13	89.90	72.03
36.5	78.27	91.18	71.37
37.0	77.73	91.65	71.24
37.5	78.13	91.58	71.55
38.0	79.05	91.09	72.01
38.5	80.17	90.26	72.36
39.0	81.30	89.15	72.48
39.5	82.43	87.88	72.44
40.0	83.58	86.58	72.36
40.5	84.81	85.34	72.37
41.0	86.13	84.13	72.46
41.5	87.50	82.90	72.54
42.0	88.87	81.61	72.53
42.5	90.17	80.34	72.44
43.0	91.35	79.22	72.37
43.5	92.37	78.38	72.39
44.0	93.21	77.78	72.50
44.5	93.88	77.28	72.55
45.0	94.38	76.71	72.41
45.5	94.71	76.07	72.04
46.0	94.87	75.51	71.63
46.5	94.85	75.30	71.43
47.0	94.70	75.56	71.56
47.5	94.47	76.13	71.91
48.0	94.21	76.70	72.26
48.5	93.98	77.05	72.41
49.0	93.76	77.10	72.30
49.5	93.52	77.01	72.02
50.0	93.17	77.01	71.75
50.5	92.62	77.32	71.61
51.0	91.80	78.01	71.61
51.5	90.64	79.04	71.63
52.0	89.16	80.32	71.61
52.5	87.49	81.80	71.56
53.0	85.80	83.39	71.55
53.5	84.26	84.97	71.60
54.0	82.90	86.48	71.69
54.5	81.61	87.87	71.71
55.0	80.20	89.14	71.49
55.5	78.33	90.27	70.71
56.0	75.36	91.20	68.73
56.5	70.40	91.87	64.68
57.0	63.00	92.21	58.10
57.5	54.11	92.16	49.87
58.0	45.72	91.74	41.94
58.5	39.42	91.35	36.01
59.0	35.88	91.88	32.96
59.5	35.19	93.20	32.79
60.0	37.40	94.28	35.26
60.5	42.56	94.80	40.35
61.0	50.07	94.83	47.49
61.5	57.74	94.41	54.52
62.0	62.06	93.47	58.01
62.5	60.65	91.77	55.66
63.0	53.77	88.93	47.82
63.5	44.08	84.65	37.31
64.0	35.18	79.69	28.03
64.5	29.30	76.59	22.44
65.0	26.97	78.20	21.09

Beamsplitter Example 5

[0052] Table 9 below illustrates another example of a coating interface **320** for 193 nm that satisfies the requirements of a flat R(s)*T(p) apodization function using a total of 30 alternating layers (n=15) of AlF_3 and NdF_3. This example provides a relatively flat R(s)*T(p) function between 35 and 55 degrees incident. In that range, the R(s)*T(p) function ranges from a maximum 74.60% to a minimum of 70.38%, or a delta of 4.33$ (±2.11%).

TABLE 9

Layer Number	Material	Mechanical Thickness (nm)	Layer Index (at 157.6 nm)	Optical Thickness (quarter-waves at 193 nm)
exit medium	fused silica	massive		
1	NdF_3	26.46	1.7	0.9323
2	AlF_3	23.86	1.417	0.7007
3	NdF_3	33.23	1.7	1.1708
4	AlF_3	44.51	1.417	1.3072
5	NdF_3	27.74	1.7	0.9774
6	AlF_3	27.66	1.417	0.8123
7	NdF_3	31.81	1.7	1.1208
8	AlF_3	58.21	1.417	1.7095
9	NdF_3	4.19	1.7	0.1476
10	AlF_3	49.37	1.417	1.4499
11	NdF_3	39.27	1.7	1.3836
12	AlF_3	43.00	1.417	1.2628
13	NdF_3	40.45	1.7	1.4252
14	AlF_3	43.96	1.417	1.2910
15	NdF_3	41.24	1.7	1.4530
16	AlF_3	44.88	1.417	1.3180
17	NdF_3	41.57	1.7	1.4646
18	AlF_3	45.85	1.417	1.3465
19	NdF_3	42.57	1.7	1.4999
20	AlF_3	65.98	1.417	1.9377
21	NdF_3	70.52	1.7	2.4846
22	AlF_3	60.70	1.417	1.7826
23	NdF_3	41.06	1.7	1.4467
24	AlF_3	122.77	1.417	3.6055
25	NdF_3	51.95	1.7	1.8304
26	AlF_3	40.83	1.417	1.1991
27	NdF_3	7.85	1.7	0.2766
28	AlF_3	61.42	1.417	1.8038
29	NdF_3	96.34	1.7	3.3944
30	AlF_3	123.13	1.417	3.6161
entrance medium	fused silica	massive		

The R(s), T(p) and the overall R(s)*T(p) functions are shown in FIG. **8** in graphical form, and are illustrated in the Table 10 below in tabular form:

TABLE 10

Wavelength 193 nm
Range 35-55 degrees
Substrate fused silica
H NdF_3
L AlF_3

angle	T(p)	R(s)	R(s) * T(p)
30.0	63.31	77.30	48.94
30.5	64.24	76.82	49.35
31.0	67.59	73.70	49.81
31.5	73.17	66.26	48.48
32.0	80.32	50.57	40.62
32.5	87.57	22.59	19.79
33.0	92.81	8.04	7.46
33.5	94.47	37.85	35.76
34.0	92.68	64.77	60.03
34.5	89.04	77.91	69.37
35.0	85.31	84.09	71.74
35.5	82.57	87.09	71.91
36.0	81.16	88.44	71.77
36.5	80.96	88.78	71.88
37.0	81.63	88.39	72.15
37.5	82.76	87.41	72.34
38.0	84.03	86.00	72.27
38.5	85.31	84.40	72.00
39.0	86.56	82.95	71.80
39.5	87.83	81.82	71.87
40.0	89.14	80.89	72.11
40.5	90.43	79.93	72.28
41.0	91.62	78.83	72.23
41.5	92.63	77.71	71.98
42.0	93.40	76.84	71.76
42.5	93.94	76.42	71.79
43.0	94.27	76.41	72.03
43.5	94.44	76.50	72.25
44.0	94.50	76.45	72.24
44.5	94.43	76.26	72.01
45.0	94.23	76.15	71.75
45.5	93.85	76.40	71.71
46.0	93.32	77.04	71.90
46.5	92.70	77.83	72.15
47.0	92.09	78.45	72.24
47.5	91.52	78.78	72.10
48.0	91.00	78.92	71.81
48.5	90.38	79.25	71.63
49.0	89.48	80.19	71.75
49.5	88.11	81.82	72.09
50.0	86.26	83.77	72.27
50.5	84.28	85.50	72.06
51.0	82.80	86.62	71.72
51.5	82.57	86.88	71.73
52.0	83.99	86.04	72.26
52.5	86.74	83.77	72.66
53.0	89.69	80.03	71.78
53.5	91.59	76.84	70.38
54.0	92.04	78.08	71.86
54.5	90.69	82.25	74.60
55.0	84.32	85.21	71.85
55.5	68.51	85.56	58.62
56.0	47.66	83.36	39.73
56.5	31.16	84.45	26.31
57.0	21.39	91.43	19.56
57.5	16.45	94.99	15.63
58.0	14.61	96.15	14.04
58.5	15.24	96.33	14.68
59.0	18.89	95.92	18.12
59.5	27.56	94.84	26.13
60.0	43.58	92.61	40.36
60.5	59.39	88.45	52.53
61.0	54.07	83.58	45.19
61.5	29.58	84.97	25.13
62.0	11.69	90.40	10.57
62.5	4.76	93.82	4.47
63.0	2.36	94.86	2.24
63.5	1.49	95.34	1.42
64.0	1.21	97.88	1.19
64.5	1.35	98.57	1.33
65.0	2.33	98.89	2.30

Beamsplitter Example 6

[0053] Table 11 below illustrates another example of a coating interface **320** for 157.6 nm that satisfies the requirements of a flat R(s)*T(p) apodization function using a total of 21 alternating layers of LaF_3 and MgF_2. This example provides a relatively flat R(s)*T(p) function between 44 and 60 degrees incident. In that range, the R(s)*T(p) function ranges from a maximum 68.08% to a minimum of 67.95%, or a delta of 0.128% (±0.064%).

TABLE 11

	Material	Index of refraction (at 157.6)	Thickness (nm)
Exit medium	CaF2	1.558	massive
Layer 1	LaF3	1.78	6.58
Layer 2	MgF2	1.465	26.99
Layer 3	LaF3	1.78	26.67
Layer 4	MgF2	1.465	13.76
Layer 5	LaF3	1.78	43.26
Layer 6	MgF2	1.465	15.96
Layer 7	LaF3	1.78	26.76
Layer 8	MgF2	1.465	22.79
Layer 9	LaF3	1.78	30.06
Layer 10	MgF2	1.465	21.23
Layer 11	LaF3	1.78	41.81
Layer 12	MgF2	1.465	30.49
Layer 13	LaF3	1.78	39.32
Layer 14	MgF2	1.465	30.48
Layer 15	LaF3	1.78	40.11
Layer 16	MgF2	1.465	31.22
Layer 17	LaF3	1.78	47.42
Layer 18	MgF2	1.465	20.04
Layer 19	LaF3	1.78	28.12
Layer 20	MgF2	1.465	89.08
Layer 21	LaF3	1.78	45.99
Entrance medium	CaF2	1.558	massive

The R(s), T(p) and the overall R(s)*T(p) functions are shown in FIG. **9** in graphical form, and are illustrated in the Table 12 below in tabular form:

TABLE 12

Wavelength 157.6 nm
Range 44-60 degrees
Substrate CaF_2
H LaF_3
L MgF_2

Angle	R(s)	T(p)	Efficiency (Rs * Tp)
30	58.9139	69.5322	40.96413078
30.5	59.2118	70.3769	41.67142927

TABLE 12-continued

Wavelength 157.6 nm
Range 44-60 degrees
Substrate CaF_2
H LaF_3
L MgF_2

Angle	R(s)	T(p)	Efficiency (Rs * Tp)
31	58.9692	71.5766	42.20814841
31.5	58.1352	73.1124	42.50403996
32	56.6385	74.9485	42.44970617
32.5	54.387	77.0295	41.89403417
33	51.2722	79.278	40.64757472
33.5	47.1894	81.5955	38.50442688
34	42.0867	83.8674	35.29702104
34.5	36.0681	85.9728	31.00875548
35	29.5641	87.7991	25.95701372
35.5	23.5225	89.2587	20.99587771
36	19.4119	90.3033	17.52958629
36.5	18.7295	90.9307	17.03086546
37	22.0851	91.1835	20.13796716
37.5	28.6865	91.1384	26.14441712
38	36.8679	90.8907	33.50949239
38.5	45.0672	90.5386	40.80321194
39	52.3501	90.1693	47.20371872
39.5	58.3732	89.851	52.44890393
40	63.1419	89.6287	56.59326413
40.5	66.8075	89.5251	59.80948118
41	69.5546	89.5433	62.28148414
41.5	71.5537	89.6718	64.16349076
42	72.9471	89.8899	65.57207524
42.5	73.851	90.1731	66.59373608
43	74.3622	90.4966	67.29526269
43.5	74.5655	90.8379	67.73373432
44	74.5416	91.1777	67.96531642
44.5	74.3703	91.4985	68.04770895
45	74.1315	91.7828	68.03996638
45.5	73.9005	92.0117	67.99710636
46	73.7397	92.1631	67.96079345
46.5	73.6918	92.2131	67.95349323
47	73.7764	92.1366	67.97506656
47.5	73.9948	91.9112	68.00950862
48	74.3402	91.5192	68.03555632
48.5	74.8088	90.9504	68.03890284
49	75.4066	90.2031	68.0190908
49.5	76.1483	89.2848	67.98885736
50	77.0487	88.2121	67.96627629
50.5	78.1109	87.01	67.96429409
51	79.3161	85.712	67.98341563
51.5	80.6216	84.3595	68.01197865
52	81.9672	83.0007	68.03334977
52.5	83.2877	81.6874	68.03555665
53	84.5248	80.4707	68.01769823
53.5	85.6345	79.3955	67.98993945
54	86.5885	78.4947	67.96738331
54.5	87.3719	77.7853	67.96249453
55	87.9786	77.267	67.97842486
55.5	88.4071	76.9249	68.00707327
56	88.6567	76.7374	68.03284651
56.5	88.7245	76.6865	68.03971369
57	88.6036	76.7707	68.02160395
57.5	88.2817	77.0131	67.9884739
58	87.7394	77.4623	67.96495725
58.5	86.9495	78.1816	67.97851029
59	85.8754	79.2247	68.03452802
59.5	84.4685	80.5999	68.08152653
60	82.6643	82.2249	67.97063801
60.5	80.3745	83.8828	67.42038109
61	77.4752	85.2016	66.01011
61.5	73.7899	85.6985	63.23683745
62	69.0744	84.9216	58.65908567
62.5	63.0206	82.6559	52.09024412
63	55.3373	79.0697	43.7550371
63.5	46.0352	74.6757	34.37710785
64	36.0758	70.1277	25.2991288
64.5	28.1251	65.998	18.5620035
65	25.8553	62.6575	16.2002846
P-V (44-60)			0.128033306

Beamsplitter Example 7

[0054] Table 13 below illustrates another example of a coating interface **320** for 157.6 nm that satisfies the requirements of a flat R(s)*T(p) apodization function using a total of 11 alternating layers of LaF_3 and MgF_2. This example provides a relatively flat R(s)*T(p) function between 44 and 60 degrees incident. In that range, the R(s)*T(p) function ranges from a maximum 63.11% to a minimum of 62.897%, or a delta of 0.21% (±0.1%).

TABLE 13

	Material	Index of refraction (at 157.6)	Thickness (nm)
Exit medium	CaF2	1.558	massive
Layer 1	LaF3	1.78	58.48
Layer 2	MgF2	1.465	60.07
Layer 3	LaF3	1.78	55.11
Layer 4	MgF2	1.465	47.98
Layer 5	LaF3	1.78	31.71
Layer 6	MgF2	1.465	40.26
Layer 7	LaF3	1.78	31
Layer 8	MgF2	1.465	38.79
Layer 9	LaF3	1.78	27.29
Layer 10	MgF2	1.465	37.73
Layer 11	LaF3	1.78	65.71
Entrance medium	CaF2	1.558	massive

The R(s), T(p) and the overall R(s)*T(p) functions are shown in FIG. **10** in graphical form, and are illustrated in the Table 14 below in tabular form:

TABLE 14

Wavelength 157.6 nm
Range 44-60 degrees
Substrate CaF_2
H LaF_3
L MgF_2

Angle	R(s)	T(p)	Efficiency (Rs * Tp)
30	4.2925	94.1131	4.039804818
30.5	4.9315	94.151	4.643056565
31	6.2593	94.054	5.887122022
31.5	8.34	93.8199	7.82457966
32	11.1766	93.4551	10.44510271
32.5	14.7035	92.9743	13.6704762
33	18.7935	92.3995	17.36510003
33.5	23.2756	91.7586	21.3573647
34	27.9613	91.0837	25.46818661
34.5	32.6691	90.4083	29.53557794
35	37.2438	89.7656	33.43212053

TABLE 14-continued

Wavelength 157.6 nm
Range 44-60 degrees
Substrate CaF_2
H LaF_3
L MgF_2

Angle	R(s)	T(p)	Efficiency (Rs * Tp)
35.5	41.5667	89.1865	37.0718849
36	45.5572	88.698	40.40832526
36.5	49.1694	88.3219	43.4273483
37	52.385	88.0741	46.13761729
37.5	55.2061	87.9641	48.56154901
38	57.6482	87.9947	50.72736065
38.5	59.7349	88.1623	52.66366174
39	61.4939	88.457	54.39565912
39.5	62.9544	88.8633	55.94335734
40	64.1456	89.3609	57.32108547
40.5	65.0956	89.9258	58.53773906
41	65.8314	90.5318	59.59835139
41.5	66.3789	91.1519	60.50562855
42	66.7633	91.76	61.26200408
42.5	67.0091	92.3328	61.87137828
43	67.1408	92.8507	62.34070279
43.5	67.1827	93.2989	62.68072009
44	67.1593	93.668	62.90677312
44.5	67.0943	93.9534	63.03737606
45	67.0105	94.1549	63.09366926
45.5	66.929	94.2753	63.09751554
46	66.8681	94.3193	63.06952384
46.5	66.8428	94.2921	63.02747982
47	66.8641	94.1984	62.98491237
47.5	66.9396	94.0412	62.95080312
48	67.0734	93.8216	62.92933705
48.5	67.2673	93.5386	62.92089068
49	67.522	93.1893	62.92327915
49.5	67.8382	92.769	62.93281976
50	68.218	92.2721	62.94618118
50.5	68.6649	91.6927	62.96070076
51	69.1845	91.0251	62.97526031
51.5	69.7837	90.2651	62.99032659
52	70.4695	89.4101	63.00685042
52.5	71.2471	88.4607	63.02568339
53	72.118	87.421	63.04627678
53.5	73.0774	86.3001	63.06586928
54	74.1132	85.1126	63.07967146
54.5	75.205	83.8797	63.08172839
55	76.3256	82.6292	63.06723268
55.5	77.4426	81.3954	63.03471404
56	78.5213	80.2182	62.98837348
56.5	79.5277	79.1413	62.93925564
57	80.4303	78.2084	62.90325075
57.5	81.2007	77.4598	62.89789982
58	81.8137	76.9248	62.9350251
58.5	82.2453	76.614	63.01141414
59	82.47	76.5069	63.09524043
59.5	82.4576	76.5366	63.11024348
60	82.168	76.572	62.91768096
60.5	81.5458	76.4036	62.30392685
61	80.5115	75.743	60.98182545
61.5	78.9521	74.2563	58.62690823
62	76.7092	71.6439	54.95746254
62.5	73.574	67.7567	49.85131446
63	69.3133	62.6944	43.45555756
63.5	63.7968	56.8124	36.2444932
64	57.3686	50.6164	29.03792005
64.5	51.5131	44.6044	22.97710918
65	49.0297	39.1471	19.19370569
P-V (44-60)			0.212343663

[0055] While specific embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. It will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined in the appended claims. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A beamsplitter comprising:
a first fluoride prism;
a second fluoride prism;
a coating interface between the first and second fluoride prisms,
wherein a (R(s) function of the beamsplitter compensates for variations of a T(p) function of the beamsplitter such that variations of an apodization function of the beamsplitter is smaller than the variation of the T(p) function; and
wherein the coating interface includes alternating layers of first and second fluoride materials, the first fluoride material has a greater refractive index than the second fluoride material.

2. The beamsplitter of claim **1**, wherein the coating interface includes alternating layers of MgF_2 and LaF_3.

3. The beamsplitter of claim **1**, wherein the coating interface includes alternating layers of NdF_3 and AlF_3.

4. The beamsplitter of claim **1**, wherein the first and second prisms include CaF_2.

5. The beamsplitter of claim **1**, wherein the overall R(s)*T(p) function of the beamsplitter varies no more than ±2.74% with reference to an average between the maximum value and the minimum value of the apodization function in the range of 35-55 degrees of incidence.

6. The beamsplitter of claim **1**, wherein the beamsplitter operates at about 157.6 nm.

7. The beamsplitter of claim **1**, wherein the beamsplitter operates at about 193 nm.

8. A beamsplitter comprising:
a first prism;
a second prism;
a coating interface between the first and second prisms,
wherein the first and second prisms include fused silica;
wherein a R(s) function of the beamsplitter compensates for variations of a T(p) function of the beamsplitter such that variations of an apodization function of the beamsplitter is smaller than the variation of the T(p) function; and
wherein the coating interface includes alternating layers of first and second fluoride materials, the first fluoride material has a greater refractive index than the second fluoride material.

9. The beamsplitter of claim **8**, wherein the coating interface includes alternating layers of MgF_2 and LaF_3.

10. The beamsplitter of claim **8**, wherein the coating interface includes alternating layers of NdF_3 and AlF_3.

11. The beamsplitter of claim **8**, wherein the overall R(s)*T(p) function of the beamsplitter varies no more than ±2.74% with reference to an average between the maximum value and the minimum value of the apodization function in the range of 35-55 degrees of incidence.

12. The beamsplitter of claim **8**, wherein the beamsplitter operates at about 157.6 nm.

13. The beamsplitter of claim **8**, wherein the beamsplitter operates at about 193 nm.

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