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(54) **REFRACTIVE/DIFFRACTIVE INFRARED IMAGER**

BRECHENDE/BEUGENDE INFRAROTABBILDUNGSOPTIK

DISPOSITIF D'IMAGERIE A INFRAROUGE PAR REFRACTION/DIFFRACTION

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- **SWANSON, G.J. et al. Dif- fractive optical elements for use in infrared systems. Optical Engineering, June 1989, Vol. 28, No. 6, pages 605-608, chapter 1,2,4, XP002900135 (cited in the application).**

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DescriptionTECHNICAL FIELD OF THE INVENTION

[0001] This invention relates to an infrared imaging lens system and, more specifically, to an IR imager using diffractive surfaces to correct for color and/or field aberrations.

[0002] A system of this type is known from US-A-5 504 628 or EP-A-0 532 267.

BACKGROUND OF THE INVENTION

[0003] It is known that different frequencies of light do not focus at the same location after passing through a lens. For this reason, color correction has been built into prior art lens systems. This is true not only for lens systems that focus visible light, but also for infrared lens systems. A typical infrared (IR) system operates over a moderate waveband, such as approximately λ 3 - 5 microns or 8 - 12 microns. Additionally, most lenses, particularly lenses with spherical surfaces, introduce field aberrations including astigmatism and coma.

[0004] Fig. 1 shows a conventional single field-of-view (FOV) imager. It includes 3 refractive elements, the objective 10, color corrector lens 12, and a field lens 14. The objective lens 10 is the primary focusing element which has the most power and is a converging lens. The objective lens collects the light from the desired object to be imaged and focuses this energy onto the detector. The objective lens is commonly made from germanium, due to germanium's high refractive index and low dispersion. Dispersion is the variation of refractive index with wavelength causing each wavelength to focus at a slightly different location. For an 8-12 micron waveband, these multiple foci would cause a blurring of the image. Thus, a color correcting lens is needed. The color corrector lens 12 is a negatively powered highly dispersive material used to bring all desired wavelengths of light to a common focus. The color corrector lens is typically made from zinc selenide. The field lens 14 is a positively powered lens used to correct field or image aberrations such as astigmatism and/or coma. The field lens is typically made from germanium.

SUMMARY OF THE INVENTION

[0005] The terms diffractive optics or diffractive optical elements refer to those optical elements that base their operation on the utilization of the wave nature of light. This broad categorization can be divided into several subsections. Diffractive lenses are elements that perform functions similar to conventional refractive lenses, e.g., they form an image. Kinoforms are diffractive elements whose phase modulation is introduced by a surface relief pattern. Binary optics are kinoforms produced by photolithographic techniques, resulting in a "stair-step" approximation to the desired profile. Each photolithography step increases the number of levels in the surface by a factor of two, hence the term binary optics. Kinoforms are highly efficient diffractive elements.

[0006] Two references on this topic are "Binary Optics" by Veldkamp et al., Scientific American, May, 1992, pp. 92-97 and "Diffractive Optical Elements For Use In Infrared Systems" by Swanson et al., Optical Engineering vol. 28. No. 6, Jun., 1989, pp. 605-608. Recently, Veldkamp has used photolithography to approximate the kinoform surface profile. More recently, we have used diamond point turning (DPT) to create the proper kinoform surface for long wavelength (10 micron) IR optics, bypassing the binary approximation.

[0007] Due to their dispersive nature, diffractive elements can be used for color correction. Diffractive optical elements are highly dispersive in that they break up white light into its component colors from red at one end of the spectrum to blue at the other end. This dispersion is opposite in sign to that of most glasses and will cancel that of most conventional lenses. Therefore, over a small wavelength band, by combining conventional optics with diffractive optics, the chromatic aberration resulting from the dispersive characteristic of the glass can be reduced.

[0008] Typically, on a glass lens, the diffractive surface is a kinoform produced by diamond point turning, patterned and etched, or the like. Kinoforms are diffractive elements whose phase modulation is introduced by a surface relief pattern. The diffractive optical surface results in a step function whose surface is cut back by precisely one wavelength of the light frequency of interest (preferably 10 microns for operation in the 8 to 12 micron range) every time their thickness increases by that amount. The pattern required to yield the holographic element is provided by adding an additional term to the aspheric equation which provides a phase shift thereto.

[0009] Fig. 2 illustrates one approach to simplifying the conventional design. This improved design is similar to the conventional design, except that it replaces the color correcting lens with a diffractive surface 16 on the objective lens 10. The diffractive surface 16 is typically diamond-point turned onto the second surface of the objective lens. In the Fig. 2 design, the diffractive surface 16 is used for color correction only.

[0010] An infrared imager is disclosed. The imager comprises a refractive objective lens, such as an infrared transmitting glass lens, having a surface with a color correcting diffractive pattern and an infrared transmitting polymeric field lens having a substantially flat surface with a first field-correcting diffractive pattern, where the first field-correcting

diffractive pattern operates to reduce aberrations of an image. In some embodiments, the imager further comprises a second field correcting diffractive pattern on the field lens, the first and second field-correcting diffractive pattern co-operating to reduce aberrations of the image. Preferably, the objective lens is a glass lens with the glass selected from the group consisting of (Se, chalcogenide glass, ZnS, ZnSe, GaAs, and TI-1173 glass.

[0011] Another infrared imager is disclosed. The imager comprises an infrared transmitting achromatic lens group. This achromatic group comprises a refractive objective lens, such as an infrared transmitting glass lens, and a second infrared transmitting lens. The second infrared transmitting lens has a substantially flat surface with a surface diffractive pattern, the surface diffractive pattern cooperating with the refractive lens to reduce chromatic aberrations. The imager further comprises an infrared transmitting polymeric field lens. The field lens has a substantially flat surface with a first field-correcting diffractive pattern, where the first field-correcting diffractive pattern operates to reduce aberrations of an image. In some embodiments, the field lens further comprises a second field-correcting diffractive pattern, the first and second field-correcting diffractive pattern cooperating to reduce aberrations of the image.

[0012] In some embodiments, either of these imagers further comprise one or more fold mirrors, windows, and/or filters. In some embodiments, the imager further comprises a chopper between the field lens and the image plane. The chopper may block or reflect the optical energy, or could comprise one or more optical elements that spoil or defocus the image. In some embodiments, flat surfaces that do not comprise diffractive surfaces comprise antireflective sub-wavelength structures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 shows a simplified view of a conventional single field-of-view (FOV) imager.

Fig. 2 shows a simplified view of an imager with a diffractive surface on the objective lens.

Fig. 3 shows simplified view of an imager with a diffractive surface on the objective lens and a polymer field lens.

Fig. 4 shows a 12° horizontal FOV imager with a diffractive surface on the objective lens.

Fig. 5 shows a 12° horizontal FOV imager according to an embodiment of the current invention.

Fig. 6 shows a 3° horizontal FOV imager according to an embodiment of the current invention.

Fig. 7 shows a 12° horizontal FOV imager.

Fig. 8 shows a 12° horizontal FOV imager.

Fig. 9 shows a chopper inserted in the optical path of an imager.

Fig. 10 shows a folded imager.

Fig. 11 shows a plot of phase vs. radius for the color correcting diffractive surface of the Fig. 7 imager.

Fig. 12 shows a plot of phase vs. radius for the first field correcting diffractive surface of the Fig. 7 imager.

Fig. 13 shows a plot of phase vs. radius for the second field correcting diffractive surface of the Fig. 7 imager.

Fig. 14 shows the theoretical MTF of the 12° FOV imager of Fig. 4.

Fig. 15 shows the theoretical MTF of the 12° FOV imager of Fig. 5.

Fig. 16 shows the theoretical MTF of the 12° FOV imager of Fig. 7.

Fig. 17 shows the theoretical MTF of the 12° FOV imager of Fig. 8.

Fig. 18 shows several types of diffractive achromatic lens groups.

Fig. 19 shows diffractive achromatic lens groups with color correcting diffractive lenses formed from alternate materials.

DETAILED DESCRIPTION OF THE INVENTION

[0014] When designing an infrared imager, several parameters are often considered. These include modulation transfer function (MTF), both on-axis and off-axis; optical transmissivity; cost; size; weight; durability; and risk. A recent design of a 12 degree horizontal field-of-view (HFOV) imager for the 8 to 12 micron infrared band showed that a conventional imager with a color correcting diffractive surface on the objective lens could deliver good performance (MTF and transmissivity), high durability, and low risk. Fig. 4 shows this initial design and Fig. 14 shows the theoretical MTF of this initial design. However, known techniques did not allow significant cost and weight reductions, while maintaining performance. To solve this problem, I investigated several new classes of designs. Two approaches, replacing both the objective and the field lens with polymer diffractive lenses, and replacing the objective lens with a polymer diffractive lens, did not prove to be practical. However, one class of designs, which Fig. 3 illustrates in simplified form, showed promise. These designs maintained the glass objective with a color correcting diffractive surface, but used a polymer diffractive lens to correct field aberrations, such as astigmatism and coma. The polymer diffractive lens uses the infrared transmitting polymeric sheet taught in copending application titled, Durable Polymeric Optical Systems, US-A-5,629,074. This sheet is fabricated into a lens by forming a diffractive pattern on one or both sides. Typically, the

diffraction pattern is embossed, but other pattern forming methods, such as etching, could be used. When embossing an IR transmitting polymeric sheet, it is preferable to first soften the sheet. Heating an IR transmitting polymeric sheet will soften it. Temperatures on the order of 150 degrees Celsius provide good results; but the diffraction pattern needs to be formed oversize to allow for shrinkage during cooling. An embossed diffraction could be a binary approximation. However, it is preferable to diamond point turn (DPT) a pure kinoform into an embossing tool.

[0015] This investigation failed to produce a design that matched the MTF performance of the Fig. 4 design. However, a slightly lower performing design was possible. This design, shown in Fig. 5, is also a 12° HFOV design, but lighter and lower cost than the Fig. 4 design. As Fig. 15 shows, the off-axis MTF performance is noticeably less than the MTF of the Fig. 4 design. The Fig. 5 imager comprises an objective lens 10, with a color correcting diffraction surface 16, a substantially flat, diffraction field lens 18, formed from an IR transmitting polymer, with a first surface diffraction pattern 20, and a second surface diffraction pattern 22. Fig. 5 also shows a stop 26, a detector window 24, and the image plane 36, but does not show either a chopper or a scan mirror, as are commonly used in some types of IR systems. Fig. 6 shows a similar imager with a 3 degree HFOV. In this embodiment, stop 26 is located near the objective lens 10 mounting surface. Table 1 gives a summary of the different figure elements.

Table 1.

Figure Elements			
Ref #	Specific Example	Functional Description	Preferred Alternates
10	TI-1173	Objective Lens	Other chalcogenide glass, Ge, ZnS, ZnSe, GaAs, Other IR transmissive materials
12	ZnSe	Color Correction Lens	Other IR transmissive materials
14	Ge	Field Lens	Other IR transmissive materials
16	Color Correcting Diffraction Surface	First Diffraction Surface	
18	Double sided diffraction polymer lens	Diffraction Field Lens	Single sided diffraction polymer lens w/ subwavelength structure, Single sided diffraction polymer lens, Other IR transmissive materials with diffraction surface (s)
20	First Field Correcting Diffraction Surface	Diffraction Field Lens First Surface	Subwavelength structure, flat surface
22	Second Field Correcting Diffraction Surface	Diffraction Field Lens Second Surface	First field correcting diffraction surface, subwavelength structure, flat surface
24	Ge	Detector Window	Other IR transmissive materials
26		Stop	Stop integrated with lens mount
28	Single sided diffraction polymer lens	Diffraction color Correction Lens	Single sided diffraction polymer lens with AR subwavelength structure, single sided diffraction lens that corrects chromatic and non-chromatic aberrations, dual sided diffraction lens that corrects chromatic and non-chromatic aberrations, Other IR transmissive materials with diffraction surface(s)

Table 1. (continued)

Figure Elements			
Ref #	Specific Example	Functional Description	Preferred Alternates
30	Two element objective with diffractive lens that corrects chromatic aberrations	Diffractive Achromat	Two element objective group with diffractive lens that corrects chromatic and non-chromatic aberrations, Multi-element objective group with diffractive lens
32	Blocking	Chopper	Defocusing
34		Fold Mirror	Multiple fold Mirrors, pivoting mirror, interface mirror

[0016] This particular design uses a diffractive field lens 18 with both a first surface diffractive pattern 20, and a second surface diffractive pattern 22. Another embodiment of this design uses only a single diffractive pattern to correct the same aberrations as this dual pattern design. The dual pattern design was chosen because first pattern 20 and second pattern 22 are each simpler than a single pattern that corrected the same aberrations. A diffractive field lens 20 with a single diffractive pattern could have the single diffractive pattern as either a first surface diffractive pattern 20 or a second surface diffractive pattern 22. One advantage of a field lens with a single diffractive pattern is that it allows the other side of the lens to comprise an anti-reflective sub-wavelength structure (a type of graded index), thus reducing Fresnel reflection losses. Physical Optics Corp. can manufacture embossing tools suitable for forming antireflective sub-wavelength structures on a flat surface of an optical element.

[0017] In an exemplary embodiment, not part of the invention the color correcting diffractive surface has been removed from objective lens 10. Instead, the color correcting diffractive surface 16 is formed on diffractive color correction lens 28, as shown in Fig. 7. In this embodiment, glass objective lens 10 and diffractive color correction lens 28 cooperate to form a diffractive achromat 30. This diffractive achromat is lower cost and lighter than a standard color correction scheme using two refractive lenses. In some applications, the low cost of polymer diffractive lenses may cause this diffractive achromat to be preferred over a diffractive surface on the objective lens. A diffractive achromat may show additional advantages when combined with a low performance lens, such as a low cost objective lens 10 with spherical surfaces. The color correcting diffractive surface 16 can be modified to also correct for aberrations due to a non-ideal objective lens, such as spherical aberrations. Alternately, the single diffractive surface could be split into 2 simpler diffractive surfaces, one on each side of diffractive lens 28. If diffractive lens 28 has only one diffractive surface, it may be preferable to form an anti-reflective sub-wavelength structure on the other surface, as described below.

[0018] Table 2 shows the prescription and Fig. 16 shows the MTF performance of an embodiment of this design. Fig. 11, Fig. 12, and Fig. 13 show the phase vs. radius plots for the color correcting diffractive surface 16, the first field correcting diffractive surface 20, and the second field correcting diffractive surface 22, respectively. It should be noted that this information is only an illustrative example and should not be construed to limit the present invention.

Table 2. Optical Design of an IR Imager

No	Element	R1	R2	Thick	Mat'l	Dia.	Other
10	Obj.	2.174	Asp.	.350	TI-1173	2.520	Surface 2: RD = 3.59789 A = .00300425 K = 0 B = .00203632 C = -.0000206998 D = .0000138271
	Airgap			.195			
28	Color Diff.	Flat	Flat	.002	Poly-mer	2.520	Surface 2: C1 = .005119 C2 = 0 C3 = 0
26	Stop Airgap			1.9475		2.196	
18	Diff. Field Lens	Flat	Flat	.0025		1.200	Surface 1: C1 = 0 C2 = -.26909 C3 = -.22201 Surface 2: C1 = .029888 C2 = 0 C3 = 0
	Airgap			.418			
24	Window Airgap	Flat	Flat	.05 .03	Ge		
36	Image						
Aspheric Eqn:							

$$Sag = \frac{CC \cdot Y^2}{1 + \sqrt{1 - (1 + K) \cdot CC^2 \cdot Y^2}} + A \cdot Y^4 + B \cdot Y^6 + C \cdot Y^8 + D \cdot Y^{10}$$

[deletion(s)]

Where, CC = 1 / RD, and Y is the semidiameter (radius)
Diffractive Eqn:

$$Sag = \left[\frac{C1 \cdot Y^2 + C2 \cdot Y^4 + C3 \cdot Y^6}{N1 - N2} - \frac{\text{Lambda}}{N1 - N2} * INT \left(\frac{C1 \cdot Y^2 + C2 \cdot Y^4 + C3 \cdot Y^6}{\text{Lambda}} \right) \right] * Ho$$

Where, N1 = 1.50, N2 = 1, Lambda = 10.2 μm, Hor = -1, and Y is the semidiameter.

[0019] Fig. 8 shows another exemplary embodiment This approach uses a conventional refractive field lens 14, with the diffractive achromat 30 from the Fig. 7 design. Fig. 17 shows that this design exhibits improved off-axis MTF performance over the Fig. 7 design.

[0020] Fig. 9 shows an infrared imager similar to Fig. 7, but incorporating a chopper 32 in front of the window 24. This chopper modulates the optical energy incident on the image plane 36, as required by some types of staring IR

systems. There are many chopper designs known in the art. One type is an optically transparent window with an opaque pattern on portions of the window. In operation, the chopper 32 spins. When the opaque portion of the chopper enters the ray bundle, it blocks optical energy (from at least a portion of the scene) from reaching the detector located at the image plane. Other choppers replace the opaque portion with an optical element(s). One such scheme uses an optical diffuser or some other optical element, such as an array of microlenses, to defocus or spoil the image at the image plane. Although these choppers use elements with optical power, they are not using them to form an image; but, instead, to spoil the image. A chopper 32 is typically located where the optical ray bundle is small, such as between the field lens 18 and the window 24. However, some designs may locate the chopper in other locations.

[0021] Fig. 10 shows an infrared imager similar to Fig. 7, but incorporating a fold mirror 34 between diffractive achromat 30 and diffractive field lens 18. The use of one or more fold mirrors and/or other elements without optical power (such as windows) are common packaging techniques. In some systems, including but not limited to scanning IR systems, a fold mirror may be mounted on a pivot. This would allow the mirror to be rotated, thus shifting the scene location at the image plane 36.

[0022] The invention is not to be construed as limited to the particular examples described herein, as these are to be regarded as illustrative, rather than restrictive. The invention is intended to cover all processes and structures that do not depart from the scope of the invention. For example, in diffractive achromat group 30, it is preferable to mount the diffractive color correction lens 28 to a fiat surface of objective lens 10. However, acceptable performance can be obtained at locations displaced from the objective lens. Additionally, the preceding examples of diffractive achromat 30 show a positive meniscus lens. However, Fig. 18 shows several different configurations of diffractive achromats. The diffractive achromats include groups with positive refractive lenses 38, such as biconvex and meniscus. The diffractive achromats also include groups with negative refractive lenses 40, such as biconcave and meniscus. Although this patent focuses on polymer-based color correcting diffractive lenses, other transparent materials with color correcting diffractive surfaces could be used instead. Fig. 19 shows diffractive achromats with thicker diffractive lenses.

[0023] This patent uses diffractive optics with kinoform patterns formed on the surface. However, other types of diffractive elements, such as binary diffractive and holographic-based diffractive elements, can be used to provide the optical corrections taught herein.

[0024] This patent has used IR transmitting optics for its examples. However, all the techniques and principles described herein are also applicable to visible optics. Instead of using IR transmitting refractive and diffractive elements, visible transmitting elements can be used. The preferred diffractive element for visible light may not be kinoform diffractive elements. However, there are many techniques known in the art, including binary and holographic, for forming diffractive optical elements for use at visible wavelengths.

Claims

1. An infrared imager comprising:

an infrared transmitting glass objective lens (10) having a surface (16) with a color correcting diffractive pattern; and
an infrared transmitting field lens (18) having a substantially flat surface (20) with a first field-correcting diffractive pattern thereon, the first field-correcting diffractive pattern operating to reduce field aberrations of an image.

2. The imager of Claim 1, further comprising a second field correcting diffractive pattern on the field lens, the first and second field-correcting diffractive patterns cooperating to reduce aberrations of the image.

3. The imager of Claim 1, wherein the objective lens (10) includes glass selected from the group consisting of Ge, chalcogenide glass, ZnS, ZnSe, GaAs, and TI-1173 glass.

4. The imager of Claim 1, wherein the objective lens (10) is part of an infrared transmitting achromatic lens group (30), the group also comprising second infrared transmitting lens (28) having a substantially flat surface with a surface diffractive pattern, the surface diffractive pattern cooperating with the objective lens (10) to reduce chromatic aberrations.

5. The imager of Claim 4, further comprising a second field-correcting diffractive pattern on the field lens (18), the first and second field-correcting diffractive patterns cooperating to reduce aberrations of the image.

6. The imager of Claim 4, wherein the objective lens (10) includes glass selected from the group consisting of Ge,

chalcogenide glass, ZnS, ZnSe, GaAs, and TI-1173 glass.

7. The imager of Claim 4, further comprising a fold mirror (34).

8. The imager of Claim 4, further comprising a chopper (32) between the field lens (18) and the image.

9. The imager of Claim 4, wherein the objective lens (10) is a meniscus lens.

10. The imager of Claim 4, wherein the imager does not use any additional elements to form the image, except elements that have no optical power.

11. The imager of Claim 10, further comprising:

an optical element selected from the group consisting of fold mirrors (34), windows (24), and filters.

12. The imager of Claim 10, further comprising:

a chopper (32) between the field lens (18) and an image plane (36).

13. The imager of Claim 12, wherein the chopper (32) includes an opaque surface to block optical energy.

14. The imager of Claim 12, wherein the chopper (32) includes a defocusing optical element to defocus the image.

15. The imager of Claim 10, wherein the objective lens (10) is refractive.

16. The imager of Claim 10, wherein both surfaces (20, 22) of the field lens (18) include diffractive patterns, the diffractive patterns cooperating to reduce aberrations of the image.

17. The imager of Claim 10, wherein the field lens (18) includes a polymer.

18. The imager of Claim 17, wherein a surface (22) of the field lens (18) other than the surface (20) having the diffractive pattern includes an anti-reflective subwavelength structure.

19. The imager of Claim 10, wherein the field lens (18) includes a polymer and the diffractive pattern is embossed.

20. The imager of Claim 10, wherein the field lens (18) includes a glass material.

21. The imager of Claim 10, wherein the surface diffractive pattern of the second infrared transmitting lens (28) further cooperates with the objective lens (10) to also reduce monochromatic aberrations.

Patentansprüche

1. Ein Infrarot-Bilderzeuger mit:

einer Infrarot-durchlassenden Objektivlinse (10) aus Glas mit einer Oberfläche (16), die ein farbberichtigendes Zerstreuungsmuster aufweist; und
einer Infrarot-durchlassenden Feldlinse (18), die eine im Wesentlichen ebene Oberfläche (20) mit einem ersten feldberichtigenden Zerstreuungsmuster darauf aufweist, das dazu dient, die Feldaberrationen eines Bildes zu reduzieren.

2. Bilderzeuger nach Anspruch 1, ferner mit einem zweiten feldberichtigenden Zerstreuungsmuster auf der Feldlinse, wobei die ersten und zweiten feldberichtigenden Zerstreuungsmuster zusammenwirken, um die Aberrationen des Bildes zu reduzieren.

3. Bilderzeuger nach Anspruch 1, wobei die Objektivlinse (10) Glas umfasst, das ausgewählt ist aus der Gruppe bestehend aus Ge, Chalkogenid-Glas, ZnS, ZnSe, GaAs, und TI-1173-Glas.

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- 5 4. Bilderzeuger nach Anspruch 1, wobei die Objektivlinse (10) Teil einer Infrarot-durchlassenden achromatischen Linsengruppe (30) ist, wobei die Gruppe auch eine zweite IR-durchlassende Linse (28) mit einer im Wesentlichen ebenen Fläche ist, die ein Oberflächenzerstreuungsmuster aufweist, das mit der Objektivlinse (10) zusammenwirkt, um die chromatischen Aberrationen zu reduzieren.
- 10 5. Bilderzeuger nach Anspruch 4, ferner mit einem zweiten feldberichtigenden Zerstreuungsmuster auf der Feldlinse (18), wobei die ersten und zweiten feldberichtigenden Zerstreuungsmuster zusammenwirken, um die Aberrationen des Bildes zu reduzieren.
- 15 6. Bilderzeuger nach Anspruch 4, wobei die Objektivlinse (10) Glas umfasst, das ausgewählt ist aus der Gruppe bestehend aus Ge, Chalkogenid-Glas, ZnS, ZnSe, GaAs, und TI-1173-Glas.
7. Bilderzeuger nach Anspruch 4, ferner mit einem Faltspiegel (34).
- 20 8. Bilderzeuger nach Anspruch 4, ferner mit einem Chopper (32) zwischen der Feldlinse (18) und dem Bild.
9. Bilderzeuger nach Anspruch 4, wobei die Objektivlinse (10) eine Meniskus-linse ist.
10. Bilderzeuger nach Anspruch 4, wobei der Bilderzeuger keine zusätzlichen Elemente zur Bilderzeugung bis auf Elemente verwendet, die keine optische Wirkung haben.
- 25 11. Bilderzeuger nach Anspruch 10, ferner mit einem optischen Element, das aus der Gruppe ausgewählt ist, die aus Faltspiegeln (34), Fenstern (24) und Filtern besteht.
- 30 12. Bilderzeuger nach Anspruch 10, ferner mit einem Chopper (32) zwischen der Feldlinse (18) und einer Bildebene (36).
13. Bilderzeuger nach Anspruch 12, wobei der Chopper (32) eine undurchlässige Oberfläche besitzt, um optische Energie zu blockieren.
- 35 14. Bilderzeuger nach Anspruch 12, wobei der Chopper (32) ein defokussierendes optisches Element zum Defokussieren des Bildes besitzt.
15. Bilderzeuger nach Anspruch 10, wobei die Objektivlinse (10) brechende Wirkung hat.
- 40 16. Bilderzeuger nach Anspruch 10, wobei beide Oberflächen (20, 22) der Feldlinse (18) zerstreue Muster aufweisen, die zusammenwirken, um die Aberrationen des Bildes zu reduzieren.
17. Bilderzeuger nach Anspruch 10, wobei die Feldlinse (18) ein Polymeres umfasst.
- 45 18. Bilderzeuger nach Anspruch 17, wobei eine Oberfläche (22) der Feldlinse (18), die nicht die Oberfläche (20) mit dem zerstreuen Muster ist, eine anti-reflektierende Sub-Wellenlängen Struktur hat.
19. Bilderzeuger nach Anspruch 10, wobei die Feldlinse (18) ein Polymeres aufweist und wobei das Zerstreuungsmuster eingeprägt ist.
- 50 20. Bilderzeuger nach Anspruch 10, wobei die Feldlinse (18) ein Glasmaterial umfasst.
21. Bilderzeuger nach Anspruch 10, wobei das zerstreue Oberflächenmuster der zweiten IR-durchlassenden Linse (28) ferner mit der Objektivlinse (10) zusammenwirkt, um auch monochromatische Aberrationen zu reduzieren.

Revendications

- 55 1. Dispositif d'imagerie à infrarouge comprenant :
- une lentille d'objectif en verre transmettant l'infrarouge (10) possédant une surface (16) pourvue d'un réseau de diffraction de correction de couleur; et

une lentille de champ transmettant l'infrarouge (18) possédant une surface essentiellement plane (20) portant un premier réseau de diffraction de correction de champ, le premier réseau de diffraction de correction de champ agissant de manière à réduire des aberrations de champ d'une image.

- 5 **2.** Dispositif d'imagerie selon la revendication 1, comportant en outre un second réseau de diffraction de correction de champ disposé sur la lentille de champ, les premier et second réseaux de diffraction de correction de champ coopérant pour réduire des aberrations de l'image.
- 10 **3.** Dispositif d'imagerie selon la revendication 1, dans lequel la lentille d'objectif inclut un verre choisi dans le groupe consistant en Ge, un verre à base de chalcogénure, ZnS, ZnSe, GaAs, et un verre Ti-1173.
- 15 **4.** Dispositif d'imagerie selon la revendication 1, dans lequel la lentille d'objectif (10) fait partie d'un groupe de lentilles achromatiques transmettant l'infrarouge (30), le groupe comprenant également une seconde lentille transmettant l'infrarouge (28) possédant une surface essentiellement plane avec un réseau de diffraction de surface, le réseau de diffraction de surface coopérant avec la lentille d'objectif (10) pour réduire des aberrations chromatiques.
- 20 **5.** Dispositif d'imagerie selon la revendication 4, comprenant en outre un second réseau de diffraction de correction de champ installé sur la lentille de champ (18), les premier et second réseaux de diffraction de correction de champ coopérant pour réduire des aberrations de l'image.
- 25 **6.** Dispositif d'imagerie selon la revendication 4, dans lequel la lentille d'objectif (10) inclut un verre choisi dans le groupe comprenant le Ge, un verre à base de chalcogénure, ZnS, ZnSe, GaAs, et un verre Ti-1173.
- 30 **7.** Dispositif d'imagerie selon la revendication 4, comprenant en outre un miroir de renvoi (34).
- 35 **8.** Dispositif d'imagerie selon la revendication 4, comprenant en outre un hacheur (32) disposé entre la lentille de champ (18) et l'image.
- 40 **9.** Dispositif d'imagerie selon la revendication 4, dans lequel la lentille d'objectif (10) est une lentille en forme de ménisque.
- 45 **10.** Dispositif d'imagerie selon la revendication 4, dans lequel le dispositif d'imagerie n'utilise pas de dispositifs additionnels pour former l'image, hormis des éléments qui n'ont aucune puissance optique.
- 50 **11.** Dispositif d'imagerie selon la revendication 10, comprenant en outre :
un élément optique choisi dans le groupe comprenant des miroirs de renvoi (34), des fenêtres (24) et des filtres.
- 55 **12.** Dispositif d'imagerie selon la revendication 10, comprenant en outre :
un hacheur (32) disposé entre la lentille de champ (18) et un plan image (36).
- 13.** Dispositif d'imagerie selon la revendication 12, dans lequel le hacheur (32) inclut une surface opaque pour bloquer une énergie optique.
- 14.** Dispositif d'imagerie selon la revendication 12, dans lequel le hacheur (32) inclut un élément optique de défocalisation pour défocaliser l'image.
- 15.** Dispositif d'imagerie selon la revendication 10, dans lequel la lentille d'objectif (10) est réfringente.
- 16.** Dispositif d'imagerie selon la revendication 10, dans lequel les deux surfaces (20,22) de la lentille de champ (18) incluent des réseaux de diffraction, les réseaux de diffraction coopérant pour réduire des aberrations de l'image.
- 17.** Dispositif d'imagerie selon la revendication 10, dans lequel la lentille de champ (18) inclut un polymère.
- 18.** Dispositif d'imagerie selon la revendication 17, dans lequel une surface (22) de la lentille de champ (18) autre que la surface (20) possédant le réseau de diffraction inclut une structure de sous-longueur d'onde anti-réflexion.

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19. Dispositif d'imagerie selon la revendication 10, dans lequel la lentille de champ (18) inclut un polymère, et le réseau de diffraction est gaufré.
- 5 20. Dispositif d'imagerie selon la revendication 10, dans lequel la lentille de champ (18) inclut un matériau formé de verre.
- 10 21. Dispositif d'imagerie selon la revendication 10, dans lequel le réseau de diffraction de surface de la seconde lentille transmettant l'infrarouge (28) coopère en outre avec la lentille d'objectif (10) pour réduire également des aberrations monochromatiques.

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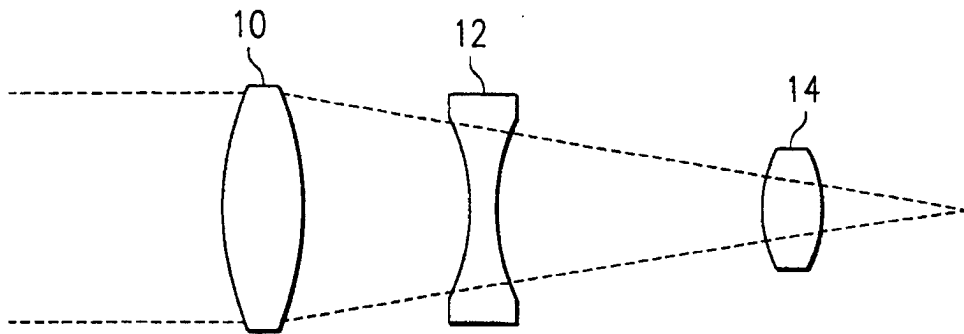


FIG. 1

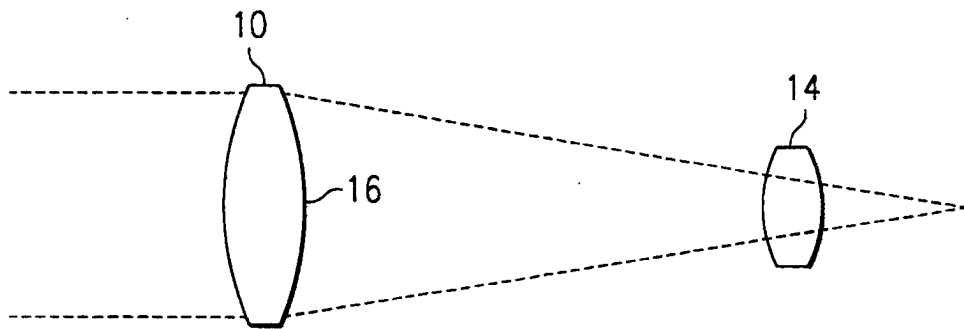


FIG. 2

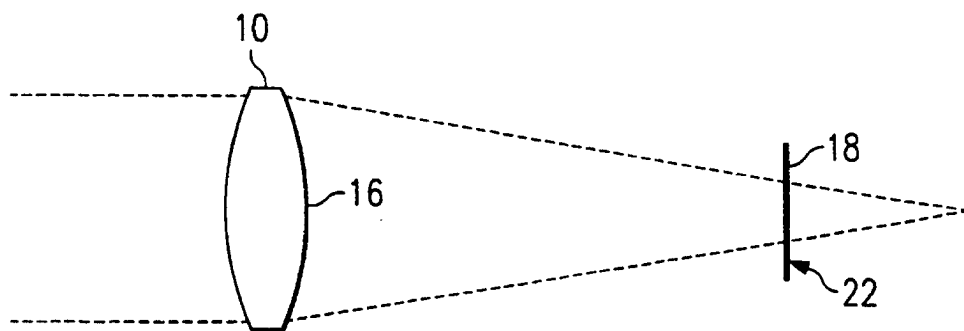
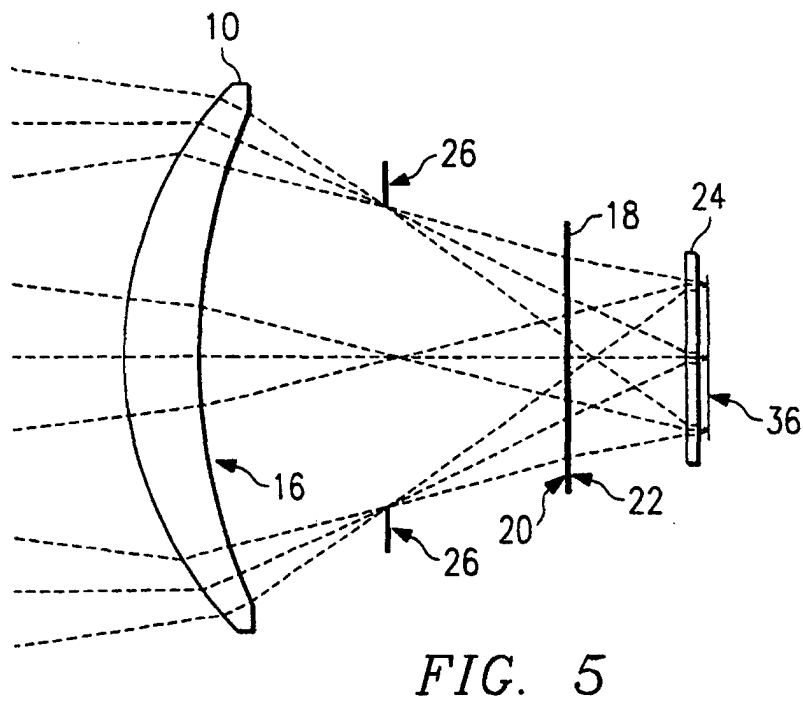
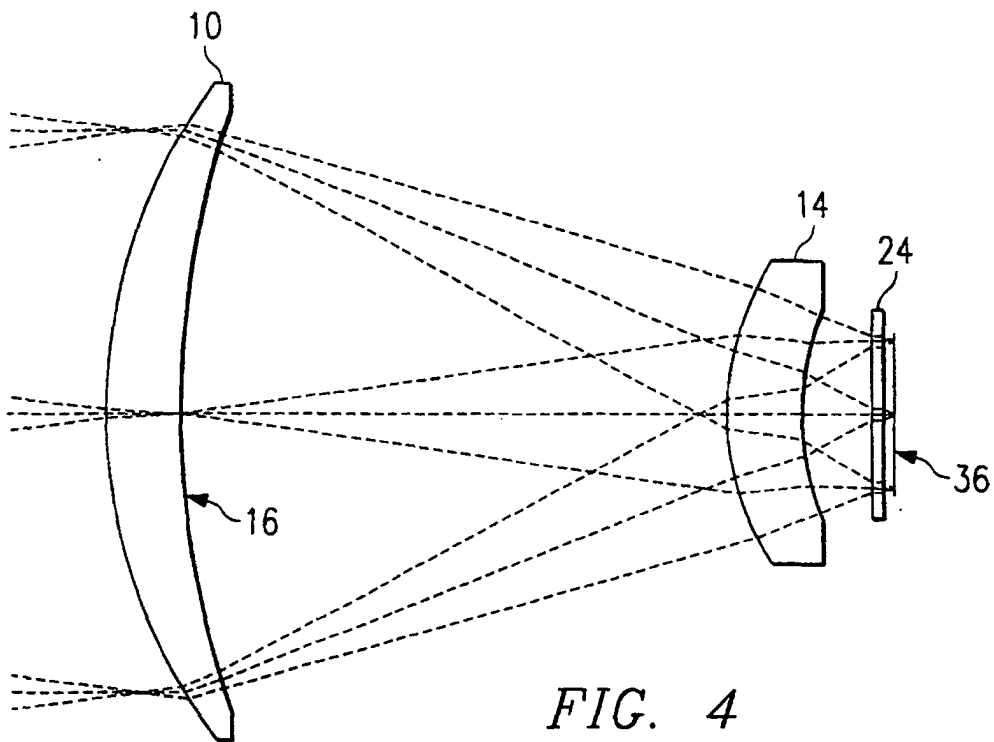
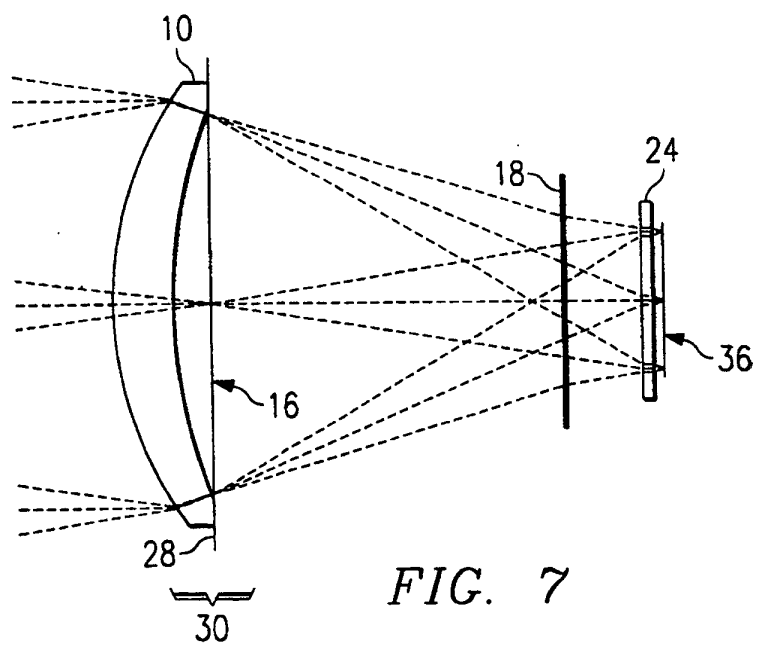
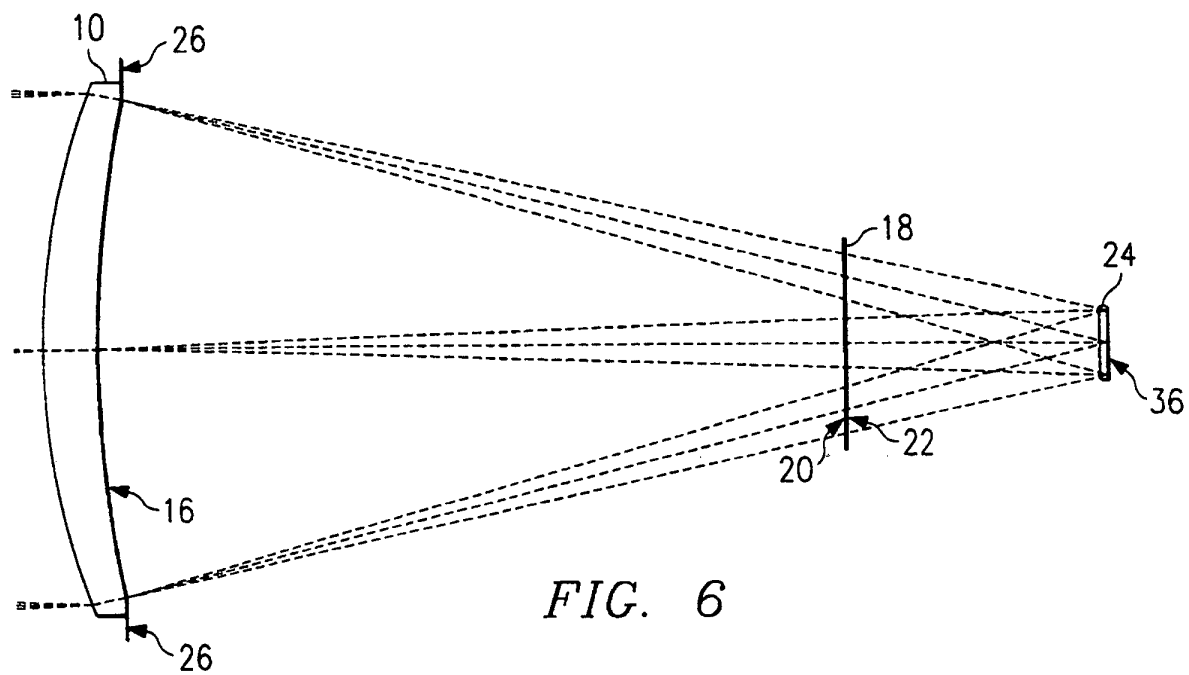
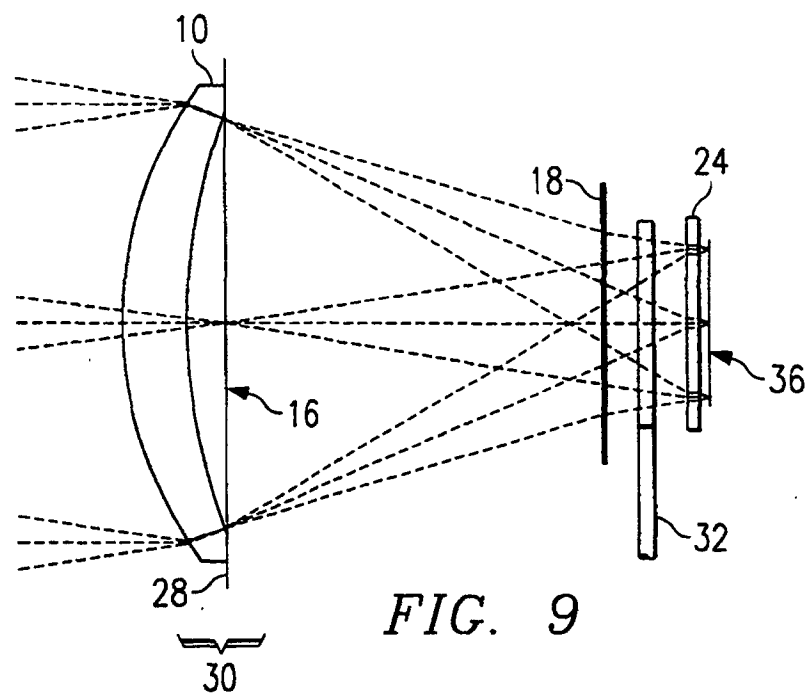
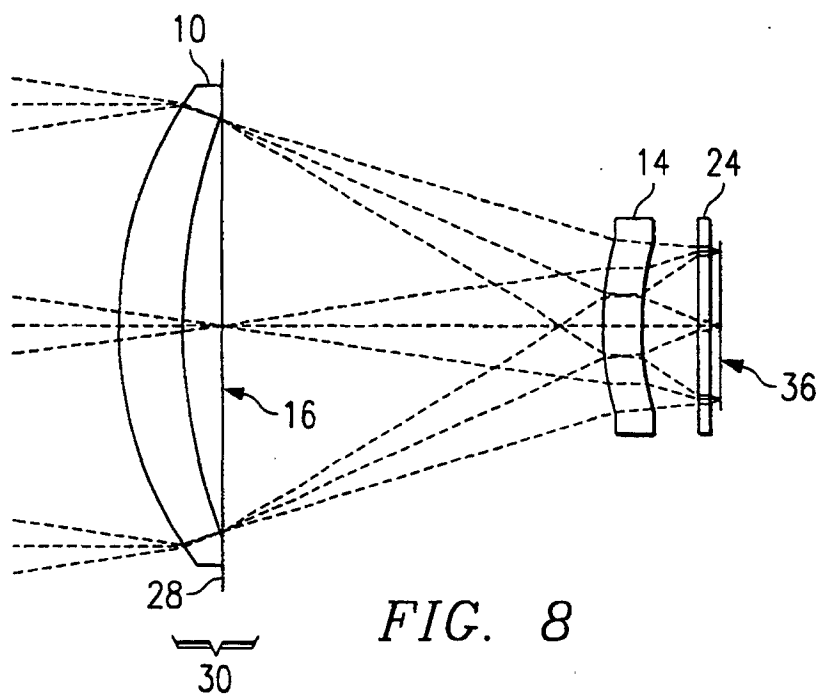


FIG. 3







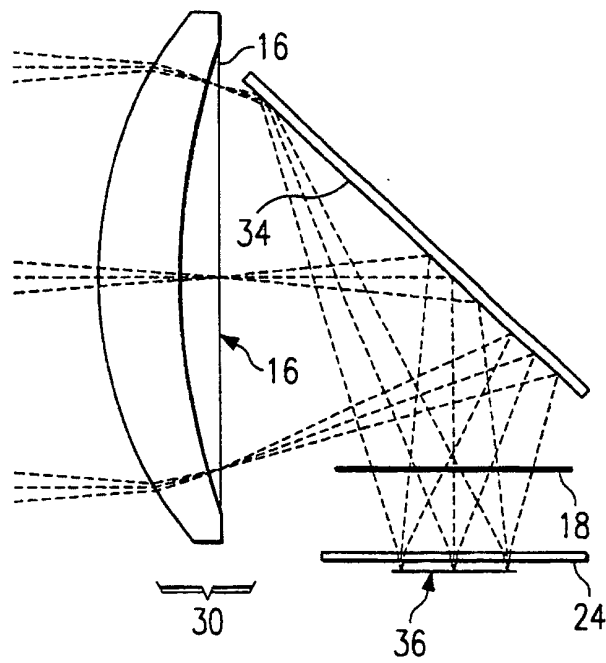


FIG. 10

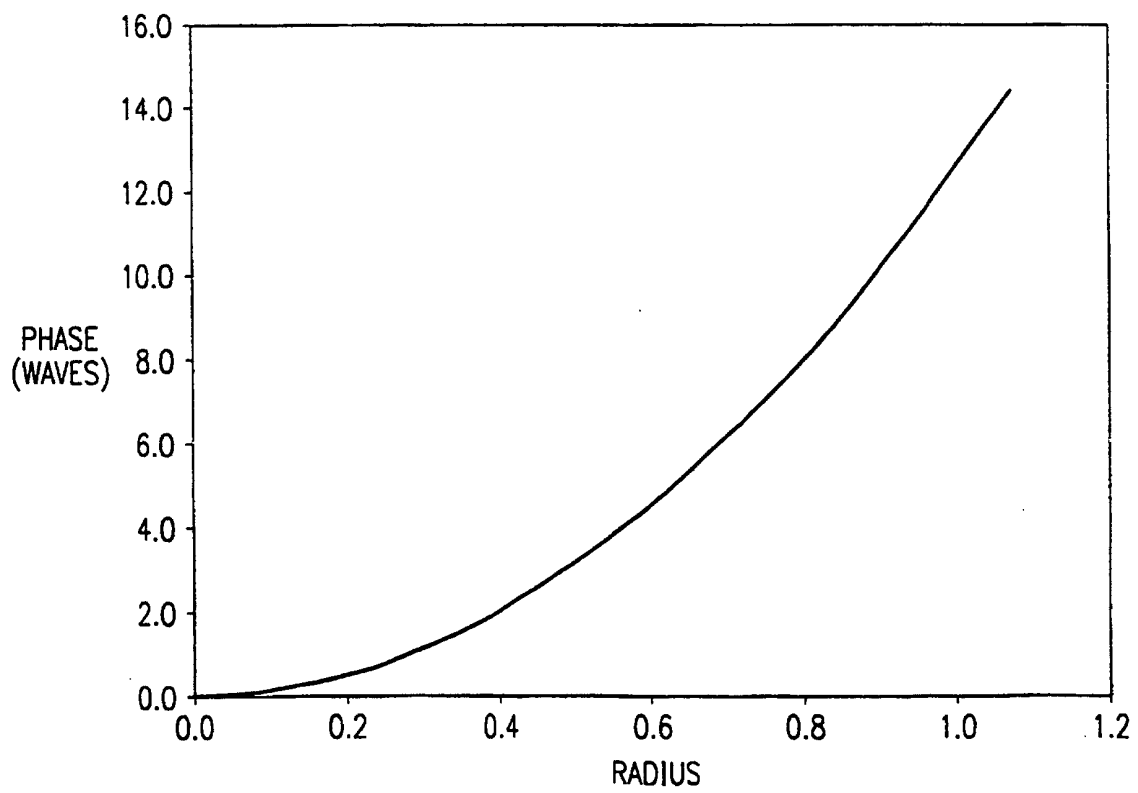


FIG. 11

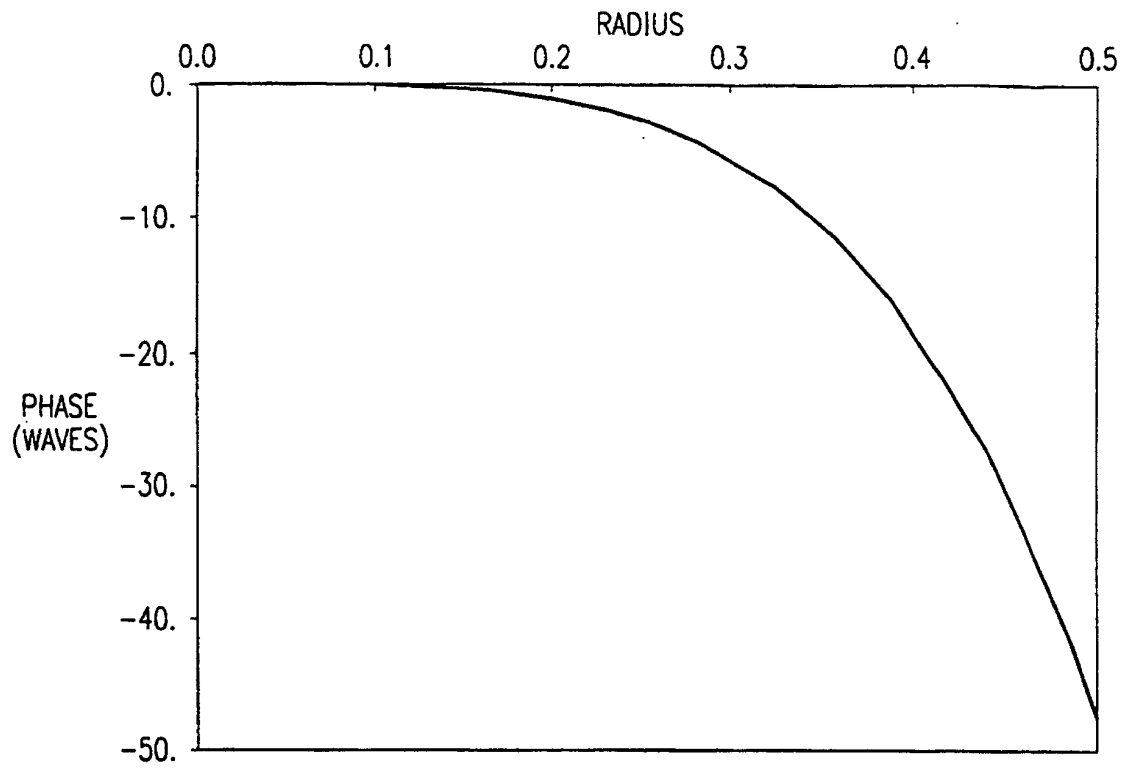


FIG. 12

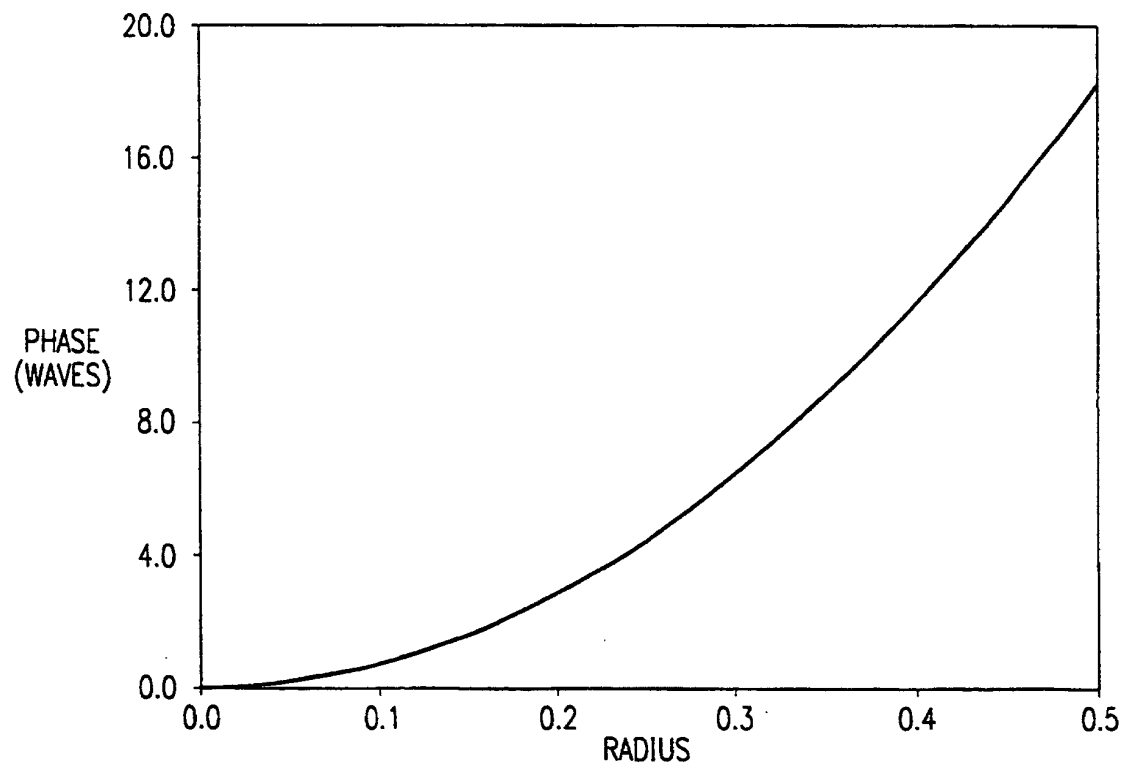


FIG. 13

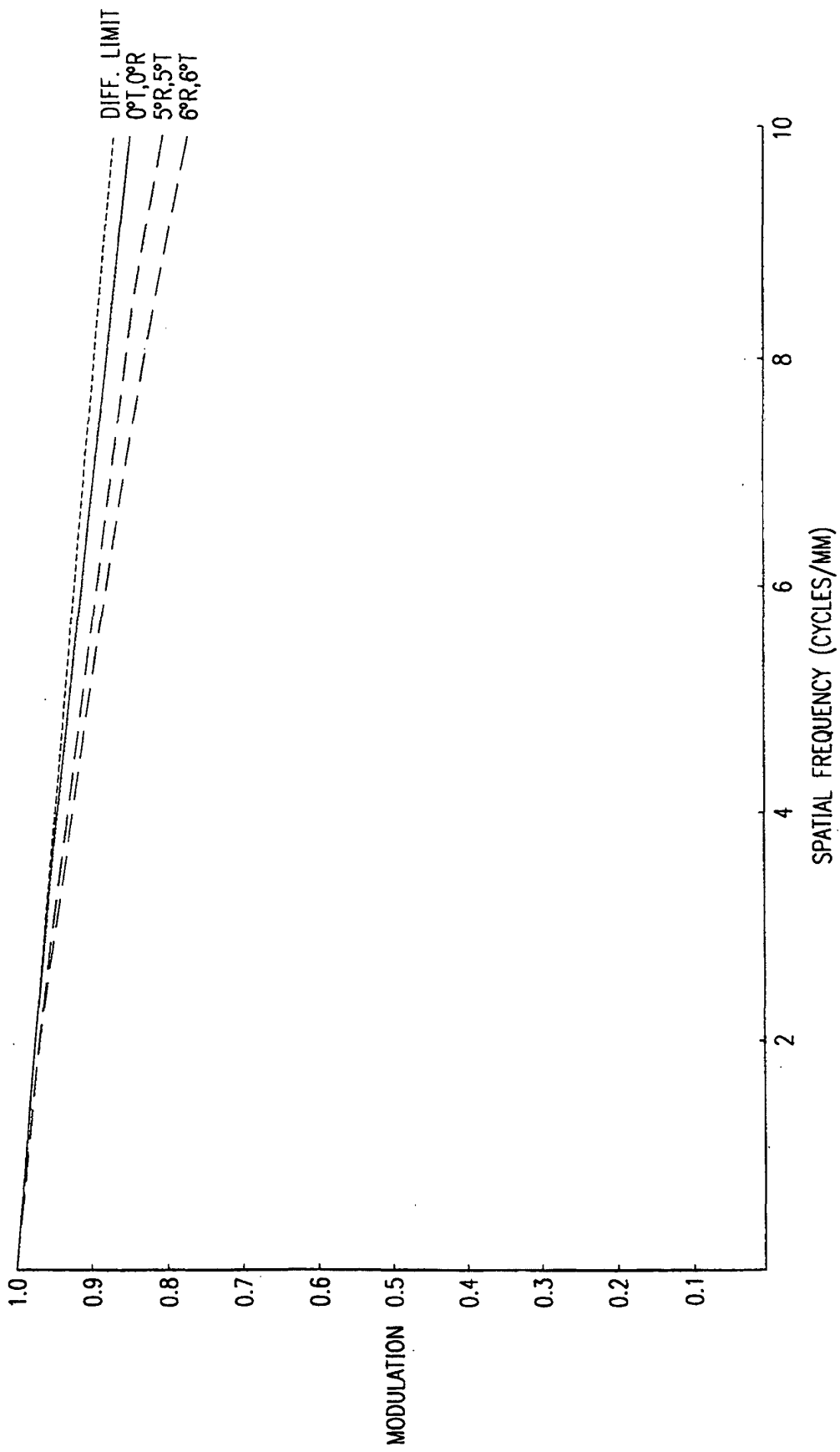


FIG. 14

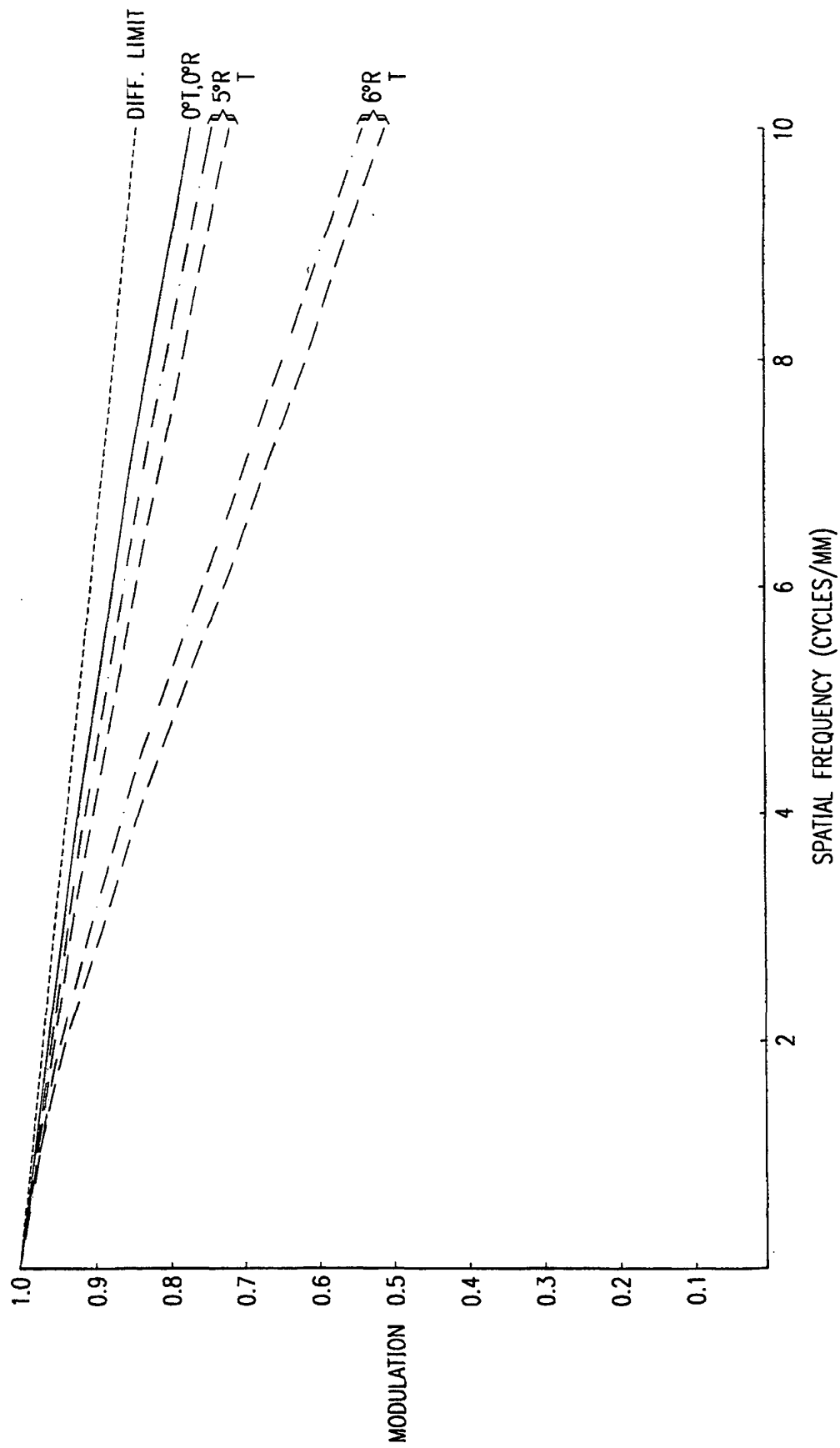


FIG. 15

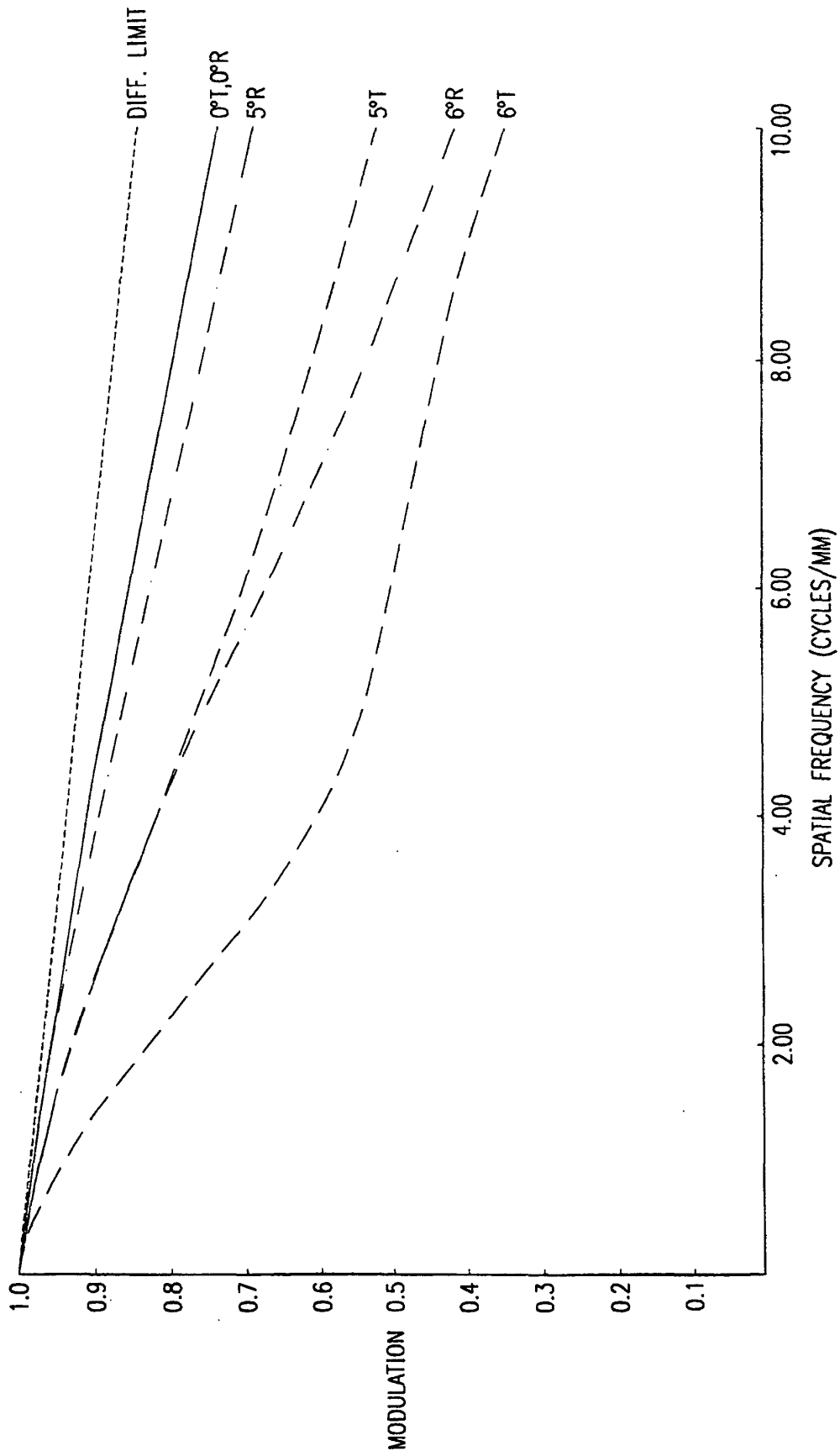


FIG. 16

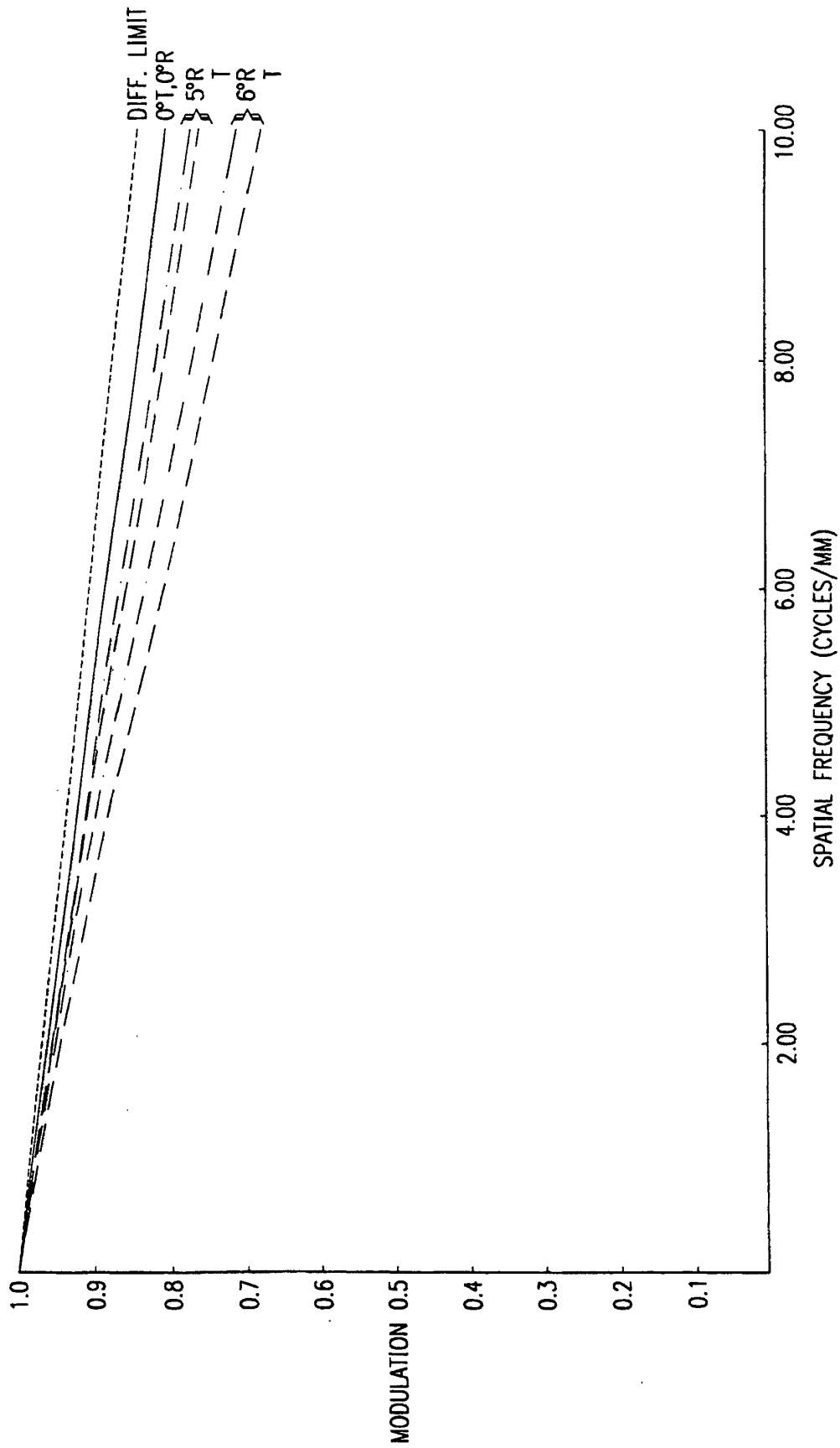


FIG. 17



FIG. 18A

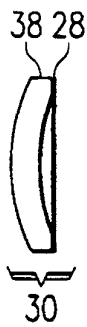


FIG. 18B

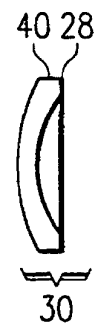


FIG. 18C



FIG. 18D

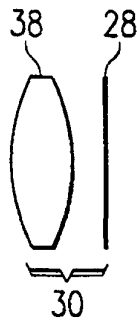


FIG. 18E

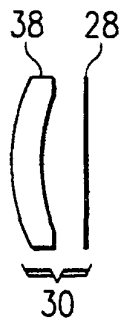


FIG. 18F



FIG. 18G

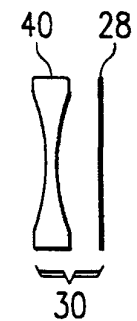


FIG. 18H



FIG. 19A



FIG. 19B

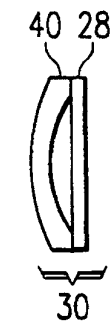


FIG. 19C

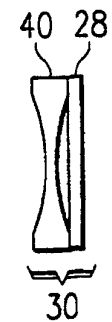


FIG. 19D