7. H.A. Macleod, *Thin Film Optical Filters, 2nd ed.* (Macmillan, New York, N.Y., 1986).
8. The computer simulations reported in this article were performed by MULTILAYER™, a product of MM Research Inc., Tucson, Ariz.

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Patent Design

Objective for Fluorescence Microscopy

BY J. BRIAN CALDWELL

Patent: U.S. 5,739,957
Issued: April 14, 1998
Title: Objective Lens System for Fluorescence Microscopes
Example: #4 of 4
Inventor: Hirokazu Konishi
Assignee: Olympus Optical Co. Ltd.

One of the main problems in microscopy is that many objects of interest are invisible under ordinary lighting conditions. Most materials that are opaque and therefore easily seen in bulk form, become nearly transparent phase objects when reduced to sub-micron thickness. One technique for enhancing the contrast of microscopic subjects is to illuminate them with UV light and then observe the emitted fluorescent radiation.

In a fluorescence microscope UV light is directed through the objective to the object by means of a beamsplitter. The objective is simply acting as a condenser for the excitation light and need only be fully corrected for the emitted light. It is important that the glass materials comprising the objective be very transparent to the excitation wavelengths and have minimal autofluorescence.

This month's design (see Fig. 1) is an apochromatic microscope objective designed for fluorescence microscopy. Special attention has been paid to glass selection to avoid autofluorescence, which would drastically reduce the contrast of the object under study. According to the inventors, the rule used in glass selection was to avoid glasses with an Abbe number less than 35 and glasses with an index greater than 1.6 having an Abbe number less than 50.

The objective described below is optimized for infinite conjugates and is intended to be used with a tube lens to achieve the desired magnification. This configuration is convenient for fluorescence microscopy because the beamsplitter for directing excitation radiation through the objective can be located in the collimated space between the tube lens and the objective. The nominal magnification for the objective when combined with a tube lens is 40X.

Figure 2 is a plot of Strehl ratio as a function of field angle. This figure shows that the objective is diffraction limited only over a narrow angular field. The optical prescription is given in Table 1. The patent specification is typical in that it only provides n_d (index of refraction at the d wavelength) and ν_d (Abbe number for d, F, and C wavelengths) for specifying materials. Since this is an apochromatic system, real glasses are substituted in order to do performance analysis. These glasses

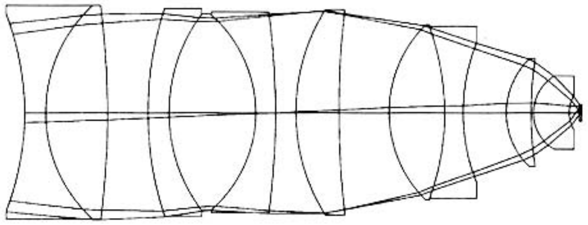

Figure 1. 9 mm EFL, 0.8 NA fluorescence microscope objective.

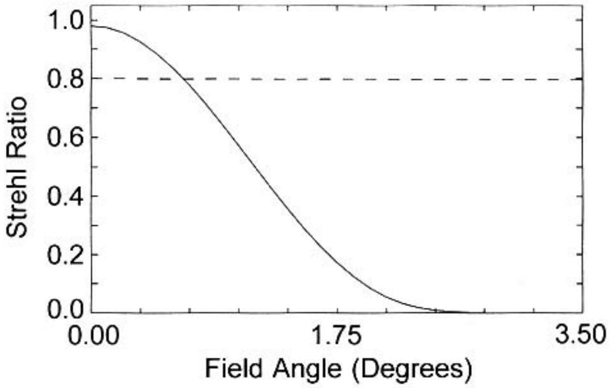

Figure 2. Strehl ratio as a function of field angle calculated for wavelengths of 0.4861 nm (F), 0.5876 nm (d), and 0.6563 nm (C), where each wavelength is weighted equally.

No.	RADIUS	THICKNESS	GLASS	DIA
0	Object	Infinity		
1	–22.040	1.700	Ohara BSL21	16.04
2	11.796	5.000	Ohara PBM8Y	17.31
3	–67.229	3.270		17.33
4	27.168	1.700	Ohara PBM8Y	16.84
5	13.357	7.000	CaF2	15.95
6	–10.509	1.600	Ohara BPM4	15.81
7	–62.596	1.650		16.28
8	15.800	3.490	Ohara FPL51Y	16.66
9	73.493	4.050		16.22
10	10.035	4.500	Ohara FPL51Y	14.20
11	–20.224	1.500	Ohara PBM8Y	13.95
12	15.403	3.490		11.36
13	6.033	2.000	Ohara FPL51Y	8.76
14	27.007	0.190		8.32
15	3.451	2.900	Ohara PHM51	5.96
16	2.609	0.852		2.71
17	Infinity	0.170	Ohara S-NSL5	1.35
18	Image			1.12

Table 1. Optical prescription where measurements are given in millimeters. Focal length is 9 mm, NA is 0.8 (f/0.625), full field-of-view is 7°.

are given in Table 1. Figure 3 shows the transverse ray aberrations at 0.0, 2.45, and 3.5° semi-field angles. This figure indicates that the limiting aberrations of the objective are coma, high order chromatic variation of coma, astigmatism, and lateral color.

***OPN* Contributing Editor J. Brian Caldwell is president of Optical Data Solutions Inc., which produces LensVIEW™, a database of optical designs found in the patent literature. Comments and suggestions are welcome at caldwell@ods-inc.com.**

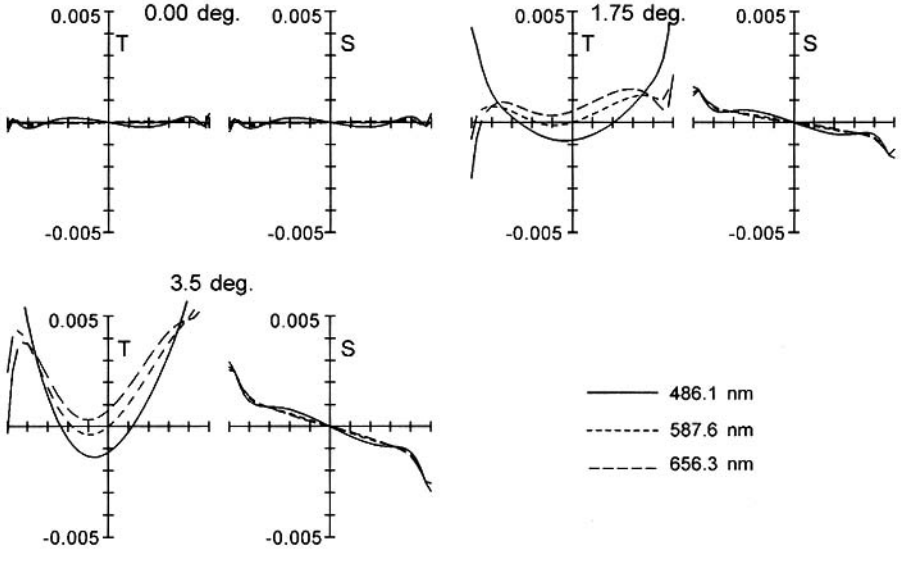

Figure 3. Transverse ray aberrations in millimeters for semi-field angles of 0.0, 2.45, and 3.50°.

Recent Research

These postdeadline papers were presented at the Conference on Lasers and Electro-Optics/International Quantum Electronics (CLEO®/IQEC) Conference, May 3–8, 1998, San Francisco, Calif.

DYNAMIC COMPENSATION OF DISPERSION AND TIME-DRIFT OF FEMTOSECOND PULSES BY USE OF SPECTRAL HOLOGRAPHY

Chromatic dispersion of ultra-fast optical pulses and arrival time drift are serious limiting factors in the performance of communications and other systems. Several methods for dispersion compensation have been demonstrated, but those methods are not capable of adapting in real-time to distortions.

The Purdue researchers conduct the initial demonstration of a spectral holographic method to dynamically compensate dispersion and time drift of femtosecond pulses with a time response up to 1 kHz. Their method is based on femtosecond spectral holography with photorefractive GaAs/AlGaAs quantum wells as dynamic holographic media. A mode-locked Ti:sapphire laser is used with a central wavelength of 836 nm. By interfering the distorted pulse with a reference pulse, they holographically record the phase changes and time shifts of the output pulse. They then reconstruct the original distortion-free pulse by reading out the hologram. Phase variations and time shifts up to 1 kHz are compensated for, and the researchers say that this is fast enough for most environment-induced phase changes.

Y. Ding and D.D. Nolte, Dept. of Physics and M.R. Melloch and A.M. Weiner, School of Electrical and Computer Engineering, Purdue Univ., West Lafayette, Ind.

UV LASING IN SEMICONDUCTOR POLYCRYSTALLINE FILMS

Hetro-epitaxial growth techniques widely used in the fabrication of semiconductor lasers are not only expensive, but also very restrictive in terms of what substrates can be used. In an attempt to overcome these restrictions, researchers have been looking for inorganic laser materials that do not require epitaxial growth. The Northwestern team reports the first demonstration of UV laser action in ZnO polycrystalline films grown on amorphous fused silica substrates.

The ZnO films (300–350 nm thick) are deposited on amorphous fused silica substrates by pulsed laser ablation. TEM analysis and X-ray diffraction measurement illustrate the polycrystalline grain structures of the films. Under optical pumping, laser action occurs in the ZnO polycrystalline films in the absence of any fabricated mirrors. Above the lasing threshold, multiple very narrow peaks emerge in the emission spectra, and the total emission intensity increases much more rapidly with the pump power. The coherent back scattering measurement indicates that the ZnO polycrystalline films are strongly scattering media, where closed loop paths for light can be formed by multiple optical scattering. When the amplification along some closed loops exceed loss, laser action occurs in these closed loops. The researchers conclude that their findings open the door to the realization of ZnO-based semiconductor lasers on many different types of substrates that are not lattice-matched to ZnO.

H. Cao, H.C. Ong, S.T. Ho, J.Y. Dai, Y.G. Zhao, X. Liu, J.Y. Wu, and R.P.H Chang, Northwestern Univ., Evanston, Ill.

AN AUTOCOMPENSATING QUANTUM KEY DISTRIBUTION SYSTEM USING POLARIZATION SPLITTING OF LIGHT

Quantum cryptographic key distribution (QKD) systems transmit cryptographic key data encoded in