Design Problem for the 2007 Topical Meeting on Optical Interference Coatings

Problem Statement

Two challenging optical thin-film filter design problems have been devised for the Optical Interference Coatings (OIC 2007) Optical Filter Design contest:

A. Triple bandpass filter
B. Non-polarizing beamsplitter

A. Triple Bandpass Filter

Requested is an optical device having three pass and four stop bands across the visible and near infrared spectral range. The incidence and exit media are air (n = 1). The device has to meet the following overall transmission requirements when illuminated with collimated light (plane waves) at normal incidence angle:

Stop band 1: 350 to 380 nm, T < 1e-4
Pass band 1: 410 to 500 nm, T > 0.9
Stop band 2: 530 to 590 nm, T < 1e-4
Pass band 2: 610 to 670 nm, T > 0.9
Stop band 3: 690 to 710 nm, T < 1e-4
Pass band 3: 730 to 740 nm, T > 0.9
Stop band 4: 760 to 900 nm, T < 1e-4

The requirements are given across continuous wavelength bands. The requirements need to be met at any wavelength across the band including the band edges. Each submission will be evaluated on a 0.001 nm grid to detect leaks in the stop and pass bands.

The substrate is non-absorptive and non-dispersive and has a refractive index of 1.45. The substrate is considered thick and parallel with surfaces 1 and 2. The optical performance of the substrate will be treated incoherently. The overall device transmission *T* is calculated:

$$T = \frac{T_1 \cdot T_2}{1 - (1 - T_1) \cdot (1 - T_2)}$$

with T_1 being the transmission through surface 1 and T_2 through surface 2.

The contestant can chose to design coatings for only side 1 or both sides 1 and 2 of the substrate.

The available design coating materials are non-absorptive and non-dispersive. Any coating material with arbitrary index in the range from 1.45 to 2.5 can be used. There is no limit to the number of materials that can be used.

The total physical coating thickness (sum of front and back surface coating) must not exceed 50,000 nm. The minimum thickness for every layer is 1 nm.

The design team invites a wide range of contributions to this problem. Conventional two material coatings, a few material coatings, coatings with very thin layers, as well as rugate coatings (expressed as homogeneous layers with at least 1 nm thickness) or any other approaches are welcome. Combining the required functionality in one coating as well as splitting the functionality in two coatings should be considered. The contestants are encouraged to accompany their designs by descriptions of their thought processes and design methods. The first goal of this contest should be to illustrate a variety of approaches and results. For the sake of a contest the contributions will be ranked by the total physical thickness (sum of thickness of front and back surface coating). The winning device is made up of the smallest possible total physical thickness (sum of thickness of front and back surface coating) while meeting all device requirements.

B. Non-polarizing Beamsplitter

A non-polarizing beamsplitter is desired that is non-polarizing in both intensity and phase. The following requirements need to be met:

Angle of incidence: 45º
Nominal center wavelength: 550 nm
$R_s = R_p$; within 2%
$40\% \leq R_s, R_p \leq 60\%$
$\Delta(R)=0^\circ$; within 1º (absolute value of the difference in the p and s reflected phase)[*]
$\Delta(T)=0^\circ$; within 1º (absolute value of the difference in the p and s transmitted phase)

[*] There are two definitions for the amplitude reflection coefficient for p-polarized light. These definitions differ by 180º. In the Abeles convention the reflected waves in s and p have no phase difference at normal incidence angle while the difference is 180º for the Mueller convention. The original design problem announcement requested $\Delta(R)=0^\circ$, but did not specify which convention to use. **Therefore, we will accept solutions that meet this requirement using either convention.** Further comments are given in the acknowledgement section below.

The challenge is to meet these requirements over a bandwidth about 550 nm. The winner will be the design that has the broadest band about 550 nm that meets the above requirements. The band must be centered about 550 nm (i.e. a design that meets the requirements from 548nm to 552nm will win over a design that meets the requirements from 548.5nm to 553nm).

For this problem, the substrate is considered semi-infinite with only one surface. The performance calculation will be for a single surface solution. Only single surface solutions will be evaluated.

Incidence material: air, n = 1.0
Substrate: glass, n = 1.52, non-dispersive, non-absorptive
Materials: 1.38, 1.45, 1.65, 1.8, 2.05, 2.2, 2.35, non-dispersive, non-absorptive
Minimum layer thickness: 5 nm

A maximum of three materials can be used in the coating design. There is no limit on the number of layers or the total physical thickness of the coating design.

Evaluation

A software program is available to evaluate the submitted designs. The software can be requested from the contest organizers by sending an email to:

Design.Contest@JDSU.com

Contestants will have the opportunity to perform the requested thin-film calculations on their submissions. The program evaluates whether or not the design passes all requirements and will return the merit values for valid submissions.

Submission

Depending on merit, a submitted design may be published in the Conference Proceedings, as part of a paper presented at OIC 2007, and later in a special OIC 2007 issue of Applied Optics. Until then, any submitted design will be known (and kept confidential) only by the OIC 2007 Design Contest team, the OIC 2007 General and Program Chair persons, and some OSA staff members.

Each participant may submit up to five solutions for each of the design problems.

Designs should only be submitted in electronic form as a DOS/Windows-based text file (i.e., a '.txt' extension). The file name should be the last name of the author shortened to 5 letters followed by three identifying characters. The first character should be 'A' or 'B' to identify the design problem. The second character should be a single digit number from '1' to '5' to differentiate between multiple submissions. The third character should be '1' or '2' to identify the first or second surface for problem A. This third character should always be '1' for problem B.

The first line of the text file should specify the name, affiliation, and address of the contestant. The second line should give an e-mail address. Then, the design should follow in the form of a table with blanks (i.e., spaces) as delimiters:

First column: refractive index of layer

Second column: physical thickness in nanometers (nm).

The first design line specifies layer 1 which adjoins the substrate. The last line describes the layer that adjoins the ambient air.

The following example illustrates submission format:

The filename Doe__A21.txt indicates the second submission by author Doe to problem A side 1. The appearance of a dataset is:

John Doe, XYZ. Inc, 1234 Farmers Lane, Eureka, CA 95472 USA
JDoe@ABC.com
1.65 121.4
1.45 24.2
... ...
... ...
2.35 51.2

The only requirement for participation in the contest is the submission of the design in the correct text format prior to the submission deadline. However, design authors are encouraged to accompany their designs with an explanation of how they arrived at their solutions.

Design Submission

The OIC 2007 conference subcommittee in charge of the design problem consists of Markus Tilsch and Karen Hendrix. Both work for JDSU, Santa Rosa, CA

Deadline for receipt of designs is March 1, 2007. All submitted designs should be sent to the design team via e-mail only:

E-mail: Design.Contest@JDSU.com

Acknowledgement

Problem B is based on a suggestion from Dr. Russell Chipman from the University of Arizona, College of Optical Sciences. For his application of a non-polarizing beam splitter he requires a component with $\Delta(R)=0^\circ$ for the Abeles convention or, equivalently, $\Delta(R)=180^\circ$ for the Mueller convention. Thank you for the support.