# Inverse design for wavelength selective thick diffractive optical element.

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Telecom Bretagne, Department of Optics, IMT-Atlantique, Technopole Brest-Iroise, CS83818, 29285, BREST, France

**email:** qiang.song@imt-atlantique.fr

**Summary**

An inverse optimization framework for designing thick diffractive optical elements is proposed to automatically find complex multilayer structure with wavelength selective effects. The design strategy is presented by optimizing the multilayer structure parameters with evolutionary algorithm based on rigorous coupling wave theory.

## Introduction

Coloured structures which result from light and subwavelength structure interaction have attracted extensive attention in the optics community [1-2]. Structures with a wavelength-selective optical element embedded in a hologram medium appeal to be good candidates to produce colorful hologram. Fabricating a patterned narrowband filter is a more complex and costly multistep photolithographic process, but such kinds of optically thick structures (>1λ)can be fabricated directly by using two photon polymerization (2PP) lithography.

In this work, we aim to develop an inverse optimization methodology that incorporates fabrication constraints of the 2PP lithography process. This work should enable the extension of diffractive optical elements to an expanded realm where white light source and colour effect are required, such as colour 3D display and security holograms

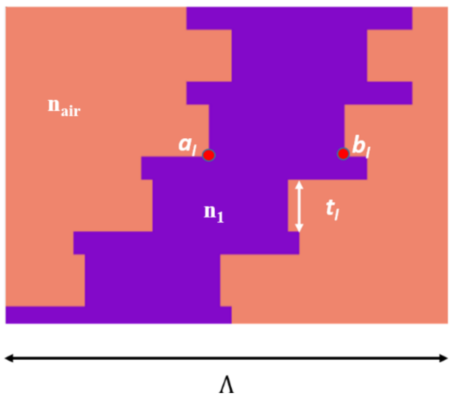



Fig.1 Layout of the multilayer periodic structure for wavelength selective device

## Discussion

An example layout of the proposed wavelength selective structure is depicted in Fig.1. From Fig.1, it is a kind of multilayer periodic structure, all the thicknesses $t_l$ and transition point $a_l$ ,$b_l$ in each layer are variables to be optimized. In this work, our goal is to design a wavelength selective optical component, so the figure of merit (FOM) is defined as follow.

$$\mathrm{FoM} = \omega_1(\eta_c - \eta_t)^2 + \omega_2 \sum_{i \neq c} {\eta_i}^2 \tag{1}$$

In eq.(1), $\eta_c$is the first order diffraction efficiency of center wavelength, and $\eta_t$is the target diffraction efficiency, $\omega_1$ and $\omega_2$ are weighting factors for center wavelength and other wavelengths, respectively. Based on the current and expected fabrication performance of 2PP lithography, additional algorithm constraints are

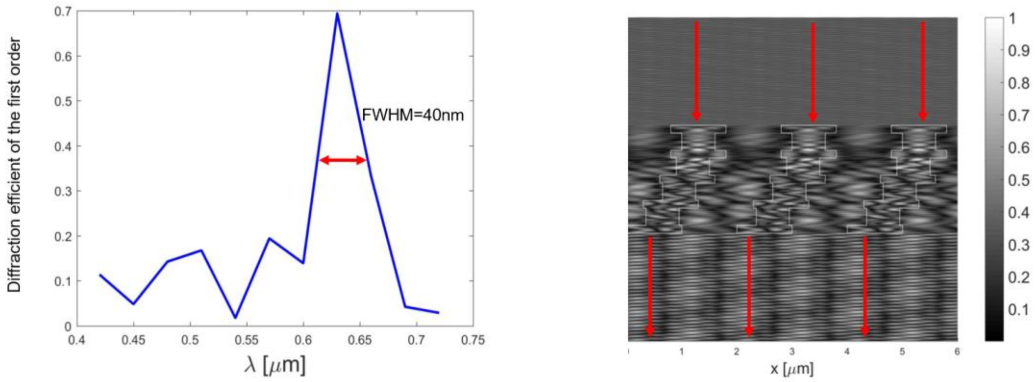
$$|b_l - a_l| \geq 0.5um,\ t_l > 1.5um \tag{2}$$

Both the object function (eq.1) and the constraints (eq.2) are the functions of the electric field E, which satisfies Maxwell's function:

$$\nabla \times \frac{1}{\boldsymbol{\mu}} \times \boldsymbol{E} - \varepsilon_l \frac{\omega^2}{c^2} \boldsymbol{E} = i\omega \boldsymbol{J} \quad (3)$$

$$\varepsilon_l = \varepsilon_1 |b_l - a_l| + (\Lambda - |b_l - a_l|) \quad (4)$$

Where $\varepsilon_l$ is the relative permittivity, and $\mu$ is 1. The electric field E can be solved using rigorous coupling wave theory [3-4]. To solve the parameters optimization problem, the genome algorithm (GA) is combined with eq. (1) - eq.(4) in this work, due to its strong global optimization capability. A multilayer structure optimization of center wavelength 650nm is carried out to verify the proposed method. Final optimization results are shown in Fig.2. From Fig.2, the structure's spectral selectively gives a FWHM width of 40nm, and diffraction efficiency of center wavelength is 70%. The FWHM is narrow enough, to be used as a narrowband filter. Fig.2 (b) shows the intensity distribution in the structure, the output field is shifted in the X direction compared to the incident light field by the diffraction effect. These simulation results demonstrate that the proposed optimization method is effective.




(a) (b)

Fig.2 Optimization results for 650nm .(a) Spectrum curve. (b) Intensity distribution inside the multilayer periodic structure

## Conclusions

We have demonstrated an effective inverse optimization model using an evolutionary algorithm based on rigorous coupling wave theory. The numerical simulations show that the multilayer periodic structure designed by the proposed methodology gives the desired wavelength selective respond. The multilayer structure is being fabricated for experimental verification.

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## References

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