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Pareto optimization of group delay response of apodized tapered fibre gratings

Konrad MARKOWSKI[1], Kazimierz JEDRZEJEWSKI[1], Tomasz OSUCH[1,2*]
[1]Institute of Electronic Systems, Warsaw University of Technology, Nowowiejska 15/19, Warsaw, 00-665, Poland
[2]National Institute of Telecommunications, Szachowa 1, Warsaw, 04-894, Poland
* T.Osuch@elka.pw.edu.pl

It was proved that practical usage of dispersion properties of chirped FBG requires shaping the envelope of the induced (by the UV exposure) refractive index changes using apodization function to achieve reduction of the oscillations in group delay characteristic [1]. Among many apodization functions, it was shown that hyperbolic tangent (tanh) profile provides better dispersion compensation properties than the others [2,3]. The tanh apodization function may be written as follows:

$$g(z)=\begin{cases}1+\tanh\left\{A\left[1-2\left(1-\frac{2}{L}z\right)^{B}\right]\right\}, z\in\left(0,\frac{L}{2}\right)\\ 1+\tanh\left\{A\left[1-2\left(\frac{2z-L}{L}\right)^{B}\right]\right\}, z\in\left(\frac{L}{2},L\right)\end{cases} \quad (1)$$

where A , B are function parameters and L is the grating length.

Although, the method in fact reduces the oscillations of the group delay response (defined as average peak to peak value of the group delay response), it also results in reduction of the operating bandwidth (defined as spectral width at a relative reference level of -10 dB) of the grating response. It occurs due to the reduction of the effective length of an apodized tapered fibre Bragg grating resulted from decreasing an amplitude of refractive index changes at both grating ends. Thus, in dispersion compensation purposes, simultaneous fulfillment of minimum group delay oscillations and maximum operating bandwidth of apodized FBG are mutually exclusive. Series of simulations were performed to demonstrate dependency between shape of the apodization and spectral width as well as oscillation factor. Results shown in Fig. 1a and Fig. 1b indicate that areas with optimal A and B parameters are located in the opposite end of the presented maps (the upper right corner for maximum spectral width and the area near the bottom left corner for minimum oscillation factor). Thus, such case may be considered as classical optimization problem with two adversative objective functions.

In order to quantitatively solve this problem and find the optimal solution(s) we propose here the use of the Pareto optimization. A solution can be called Pareto optimal (i.e. non-dominated) if no solution in the set are dominated by any other solutions in the set [4]. For analyzed tanh(A,B) apodized TFBG certain constrains has been established: maximum oscillation factor of 4ps and minimum spectral width of 3.6nm. Fig. 2a shows all possible solutions that meet these assumptions, noted in the figure with grey transparent field.

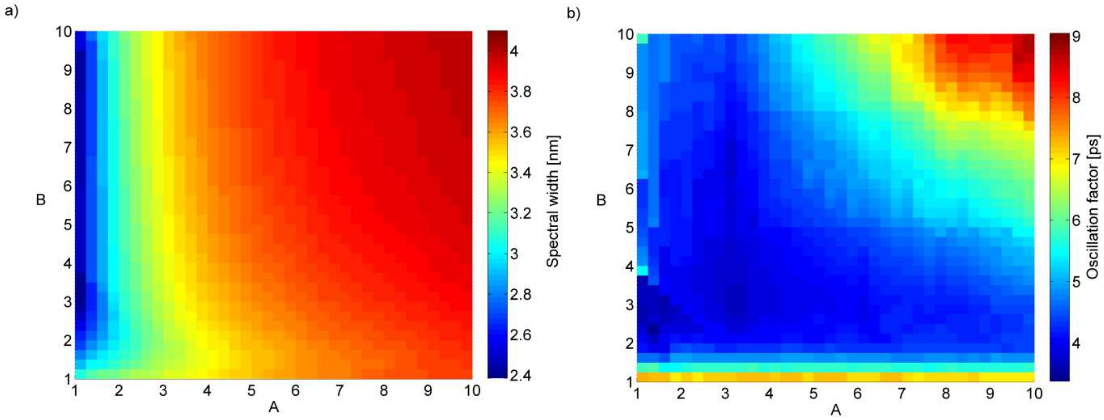

Fig. 1 Maps of a) spectral width and b) oscillation factor of apodized TFBG reflection and group delay characteristics for various A and B parameters of tanh function

However, the best, i. e. Pareto optimal, are only three of them, circled in the graph and marked with arrows. Thus, one may summarize, that the best apodization profiles are tanh functions with A and B pairs indicated in Fig. 2a. The group delay response of the optimally apodized (i.e. with A=3 and B=6.2) TFBG is presented in Fig. 2b.

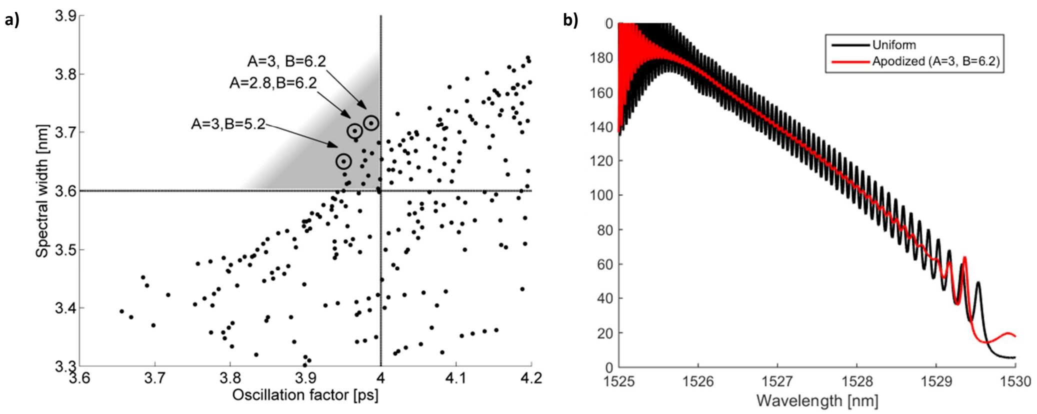

Fig. 2 Set of the solutions that fulfill established criteria for spectral width and oscillation factor with indicated Pareto frontier.

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