The multiple channel acoustooptic tunable filter with super narrow optical linewidth based on the set of multi-reflector beam expanders

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The new architecture of multiple channel noncollinear acoustooptic tunable filter (AOTF) based on multi-reflector beam expanders is presented. It provides simultaneous multiple drop of individual wavelength at different fiber output by single SAW frequency operation.

Keywords: guided-wave optics, acoustooptics, tunable filters, DWDM

Introduction

Noncollinear acoustooptic tunable filters (AOTF) [1, 2] based on multi-reflector (MR) beam expanders [3, 4] overcomes some traditional restrictions of acoustooptics and have some advantages to it's competitive technologies since it will have the smaller size, thinner linewidth, better thermostability, etc. [5, 6] Here are presented additional advantages of MR-AOTF that provides simultaneous multiple drop of individual wavelength from the set of MR-beam expanders coupled with different fibers output [1, 2]. Device operates at single SAW frequency that totally eliminates “coherent crosstalk”, due to the interaction of the lightwave with several acoustic waves that is traditional for other types of AOTF. Independent wavelength drops provided by electrooptic/thermooptic individual tuning of refractive index in the beam expanders vicinity.

Principal description

The principal view of the device is shown on Fig.1. It contains monomode planar and strip waveguide structures, interdigital transducer (IDT) for excitation of SAW, and a set of individually tuning multi-reflector optical beam expanders (BE) [3, 4] that further evolves the fruitful idea of grating beam expanders. The work of multi-channel AOTF can be described as follows [1, 2, 5]. Let optical beam of multiple wavelengths within spectrum range $\Delta\lambda$ comes from the input Fiber "in" to the input strip waveguide. Then it passed through optical beam expander that contains an array of multiple partially reflected mirrors. It extends the optical beam and transforms it to the planar optical waveguide. The efficiency of transformation depends on device parameters and in optimal conditions can be as much as 90%. Than the expanded optical beam comes to the area of acoustooptic interaction and diffracts by SAW. Expanded optical beam contains a set of angular spectrum components but only one of them of the largest intensity satisfied the Bragg conditions and comes into interaction with SAW. This spectral component is chosen by SAW and changes the angle of propagation by the double Bragg angle and directes to the beam expander of the drop channels. These beam expanders works as a reciprocal optical elements. They can transform wide optical beam to the output "drop" fibers 1-4. However, it picks up (drops) only those optical beams that at every desired optical wavelength have the proper designed direction of propagation, depending of the parameters of the beam expander (angle and period of reflectors, as well as refractive index in the strip waveguide vicinity). By changing the SAW frequency due to the Bragg conditions one can change the direction of propagation of the diffracted beam that enter the set of beam expanders and thus arrange wide tuning the optical wavelength that are individually dropped by beam expanders of the multi-channel AOTF [1, 2].

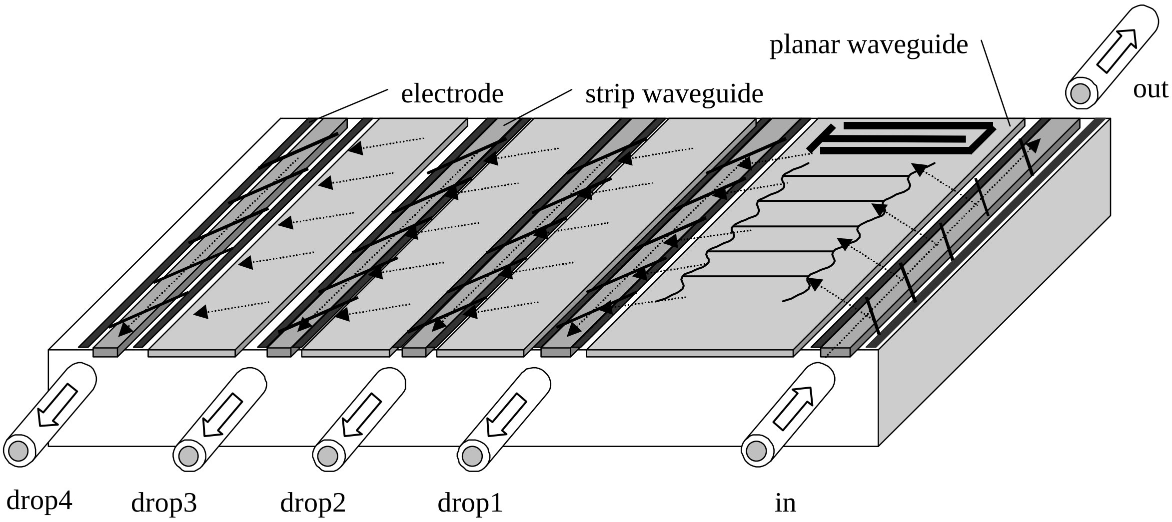

Fig.1. Principal view of the multiple channel acoustooptic tunable filters with multi-reflector beam expanders.

Results of simulations

The quantitative descriptions of the AOTF is very complicated thus the first reasonable quantitative estimates had be done by simple and evident approximation analyse [1, 2, 5] based only on the calculation of beam expander spectrum [5]. Now present more precise simulations of AOTF performances based on phenomenological descriptions of the properties of reflector array as a set of parameters R, T, and α (reflection and transmission coefficients and scattering losses, respectively).

For the simplicity the lateral distribution of optical filed of TM guided mode in the strip waveguide is described by Gaussian function with the half width w_0=3.25 μm that good adjusts the real optical filed distribution. The reflector spacing d=10 μm and waveguide effective refractive index Nm=2.31 are chosen from the condition of 15th order interference of the beam expander sub-beams at central optical wavelength 1.54 μm. Reflector apertures regarded infinitive that hardly simplifies the simulations as optical spectrum of beam expander can be descried as a sum of analytic functions [5]. Angular optical spectrum of the beam expander looks like the spectrum of Michelson echelon and is used to calculate the optical field at any point of optical waveguide by reverse Fourier transformation. The SAW aperture is rather large (several millimetres) that provides Bragg regime of acouistooptic interactions. Thus acoustooptic Bragg sell chose part of the beam expander spectrum that forms the wide optical beam with the aperture function generally described by apodisation of reflector coefficients. By known spectrum that leaves acoustooptic area we calculate optical field that enters the beam expanders of "drop" channels. The simulated signal from every drop channels is calculated taking into account multiple reflection and interference of reflected sub-beams from every reflector. The efficiency of transformation of wide optical beam into guided mode of strip waveguide is calculated by overlap integral of input optical field with that of guided mode of TM polarisation. The other (TE) polarisation is not take into account as the reflectors are arranged close to Brewster angle and influence of TE guided wave on device performances is negligible.

The response of the tunable filter at different drop channels and single operated SAW wavelengths are shown on Fig.2 for the case of 25 GHz ITU grid. It is well visible that by the change of refractive index in the vicinity of beam expanders one can individually tune the drop wavelength. The tuning range corresponds to 0.06% of the refractive index change per ITU wavelength channel. Device provides good extinction ratio (-29 dB) between neighbour channels and internal losses around -3.7 dB. To decrease optical losses one need to optimise the waveguide's width and reflector spacing of the beam expanders, but this extends the used proposition that reflected beams have a very small area of intersection that allow us use infinite aperture function of reflector beams.

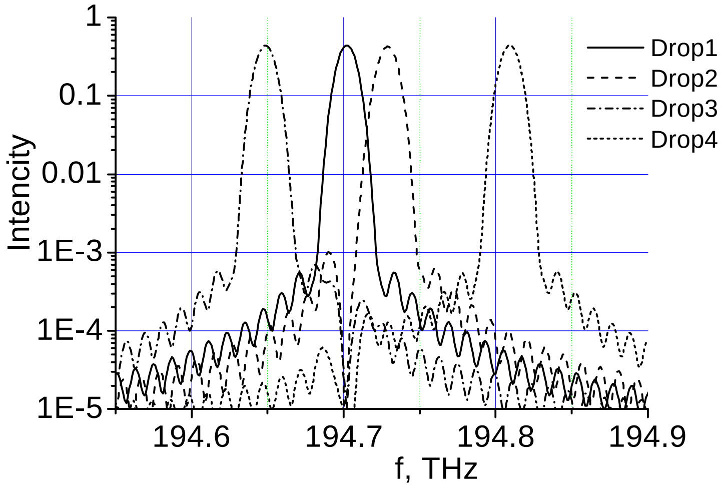

Fig.2. The response of AOTF at different drop channels wide tuned by the single SAW frequency (700 MHz). dNm/Nm=0.0000, 0.0006, -0.0012 and 0.0024 for drop channels 1-4, respectively. N=580, d=10 µm , total aperture is 0.58 cm.

Conclusions

Presented results of small-size multi-channel AOTF are very promising and may stimulate experimental investigation and development of the novel type of AOTF that can make the base of the future DWDM fiber optical networks with 25 GHz and 12.5 GHz wavelength ITU grid.

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