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Tunable Acousto-Optical Filters, Multiplexers and Lasers in $LiNbO_3$

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By combining acousto-optical polarization converters and passive polarization splitters in various ways on a single (X-cut) $LiNbO_3$ substrate a whole family of tunable integrated optical WDM-devices has been developed. Among them are wavelength filters, wavelength-selective switches and add-drop multiplexers[1]. They offer fast and broad tunability. Due to their unique multi-wavelength operation capability simplified architectures of optical cross-connects and add-drop nodes can be realized. By fabricating these devices in erbium-diffusion doped $LiNbO_3$ internal amplification can be added by optical pumping. Moreover, by optical feedback in a cavity even lasing can be achieved with a tunable emission wavelength. In this contribution, the current state-of-the-art of tunable, acousto-optical devices in $LiNbO_3$ is reviewed, illustrated by a number of selected examples.

The best known acousto-optical devices are tunable filters. They have been demonstrated as polarization-dependent and -independent devices, as single- and double-stage filters with and without polarizers or polarization splitters integrated on the same substrate. The most advanced design for polarization-independent double-stage operation is shown in Fig. 1[2]. It consists of four integrated polarization splitters and two acousto-optical polarization converters embedded in one arm of an acoustical directional coupler for guided surface acoustic waves yielding a weighted acousto-optical coupling. With a fiber-pigtailed and packaged device high sidelobe suppression (> 30 dB), low insertion loss (< 5 dB), small polarization dependence (< 0.5 dB), and a wide tuning range (> 80 nm) have been achieved.

The latest add-drop-multiplexer [1] is shown in Fig. 2; it has four passive polarization splitters and four acousto-optical polarization converters monolithically integrated on the same chip.Two of them only serve as frequency shifters to compensate the shift induced by the two acousto-optical switches. Good results have been obtained: the extinction of the dropped wavelength channel is >25 dB due to the double-stage filtering. The sidelobe suppression of the dropped channel is >15 dB and there is practically no crosstalk from the add-channel to the dropped signal due to the spatial separation of the add-and drop sections.

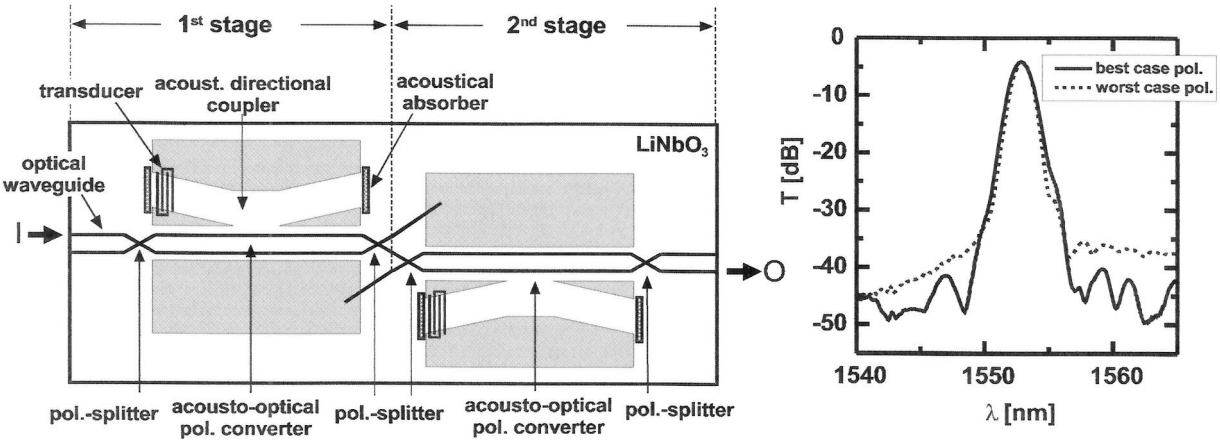

Fig. 1: Polarization independent, double-stage wavelength filter

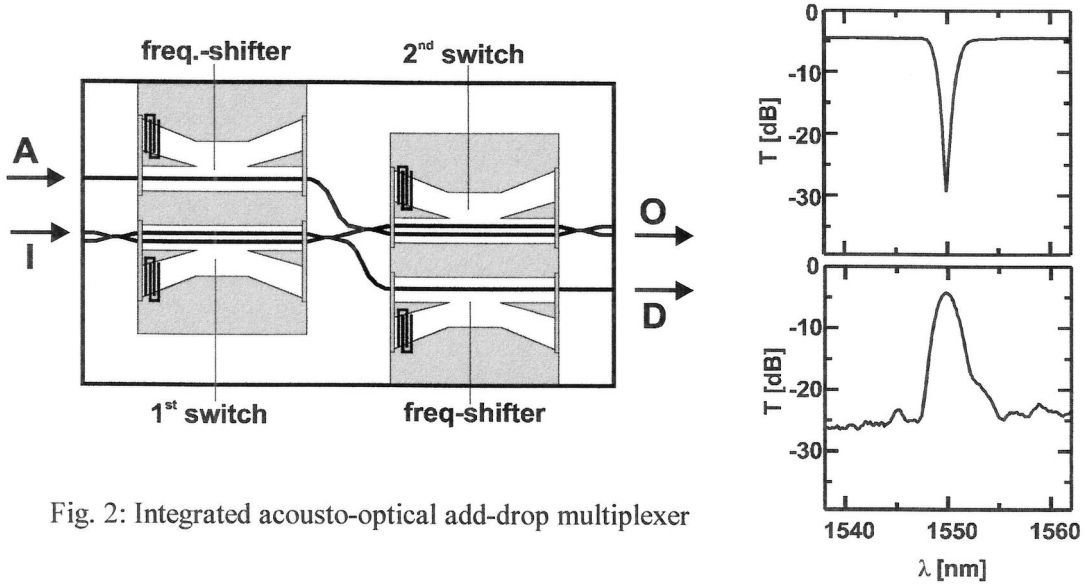

Fig. 2: Integrated acousto-optical add-drop multiplexer

A special combination of polarization-dependent, single-stage filter and frequency shifter has been fabricated in an erbium-diffusion doped substrate to develop a tunable laser [3]. One polarization splitter serves as coupler for the $\lambda = 1480$ nm pump. A gold and a dielectric endface mirror form the waveguide laser cavity. Threshold is achieved if the internal optical gain compensates the round-trip losses. As the gain is wavelength-dependent and due to a nonideal cavity lasing is not yet observed in the whole "erbium-window" 1530 nm $< \lambda <$ 1610 nm. The tuning characteristics of the fiber-pigtailed, packaged and laser-diode pumped device is shown in Fig.3.

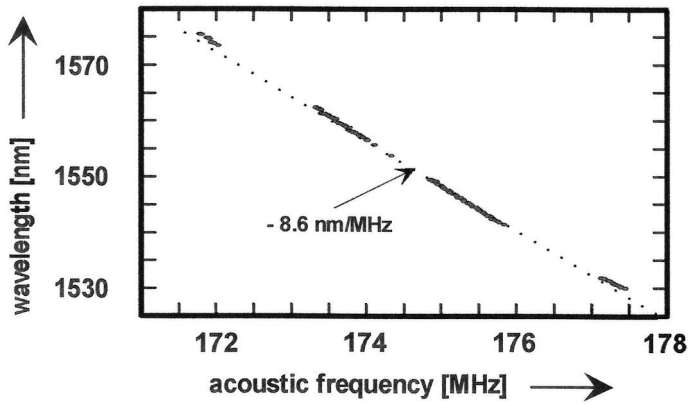

Fig. 3: Tuning characteristics of the integrated acousto optical laser

In conclusion, a variety of attractive monolithically integrated, acousto-optical devices has been developed in $LiNbO_3$. Due to their tunability they are ideal candidates for the construction of flexible, reconfigurable WDM-networks.

References:

[1] H. Herrmann, A. Modlich, Th. Müller, W. Sohler, F.Wehrmann: "Advanced integrated acousto-optical switches, add-drop multiplexer and WDM cross-connects", Proc. European Conference on Integrated Optics (ECIO'97), Stockholm, pp. 578-581 (1997)

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[3] K. Schäfer, I. Baumann, W. Sohler, H. Suche, S. Westenhöfer: "Diode-pumped and packaged, acousto-optically tunable Ti:Er:$LiNbO_3$-waveguide laser of wide tuning range", submitted to IEEE J. Quantum Electronics