Spectral Characteristics of an Integrated Tunable Frequency Shifted Feedback Laser in Erbium Doped Lithium Niobate

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An acoustooptically tunable integrated Frequency Shifted Feedback (FSF) laser is developed and its spectral properties are investigated experimentally. The design of the laser is schematically shown in figure 1. It is fabricated in an Er diffusion-doped $LiNbO_3$ substrate and has Ti indiffused optical channel waveguides. The laser resonator is formed by dielectric mirrors deposited on the polished waveguide end faces. An intracavity acoustooptical (AO) filter is used as a wavelength tuning element. Through the AO interaction, the excited surface acoustic wave (SAW) induces a polarization conversion of a selected optical wavelength which is then separated by the polarization splitter. The waveguide path of the intracavity laser field is indicated by the dotted line in the figure and the corresponding states of polarization of the internal laser field are shown inside the circles when the laser is pumped in TM polarization. This conversion process is accompanied by a frequency shift of the converted wave by the frequency of the driving SAW (here, ~170 MHz). During each round trip the laser field undergoes two polarization conversions with two frequency shifts in the same direction. As a result of this continuous frequency shift, the linewidth of the spectral emission is broadened. When this laser is suitably pumped with a diode laser of wavelength 1480 nm, the emission wavelength is continuously tunable from 1530 to 1580 nm by tuning the SAW frequency with a slope of –8 nm/MHz[1].

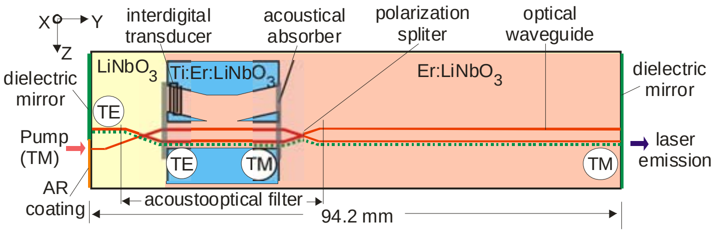

Figure 1: Schematic diagram of the acoustooptically tunable FSF laser in Ti:Er:$LiNbO_3$ waveguide. X, Y, Z are the crystal axes.

The measured (with a resolution of 10 pm) spectral linewidth of the laser emission is ~180 pm (figure 2(a)). When this FSF laser output is coupled directly to a fast photodiode, the RF spectrum of the photodiode current shows (figure 2(b)) that the spectral power is concentrated at frequencies of integer multiples of 711 MHz which is exactly equal to the free spectral range (FSR) of the laser cavity. This can be interpreted as the beating of the longitudinal modes present in the optical spectrum. There is a comb of running frequency components with a separation of FSR under the spectral envelope and they are correlated in phase. The frequency chirp rate is given by the total frequency shift per round trip time which is 2.43×10^{17} Hz/sec here and highly linear.

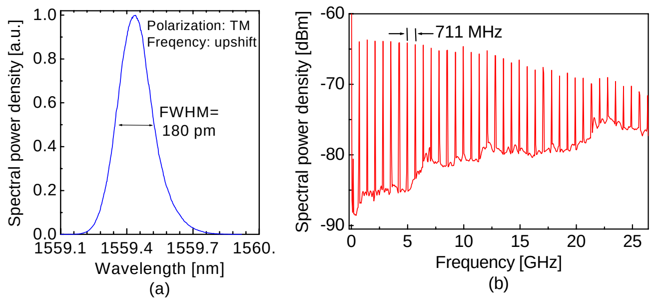

Figure 2: (a) Spectrum of the FSF laser output in TM polarization (frequency upshift); (b) Its RF power spectrum when directly detected by a fast photodiode.

These unique features of the FSF laser emission promise interesting applications. For instance, such lasers can be used in Optical Frequency Domain Reflectometry (OFDR) to analyze long optical fiber lines with high spatial resolution. As an example, a Michelson interferometer setup with one arm formed by an optical fiber has been investigated. In figure 3 the RF-spectrum at the output of the interferometer is shown. Beat signals in the spectrum can be observed as a result of reflections at the front and rear end of the fiber (labeled "f " and "r", respectively). A detection bandwidth of slightly larger than the FSR is sufficient as each reflection produces always a beat signal within the FSR. However, the "order" of the beat signal has to be determined to evaluate the optical path length. This can be done using a frequency modulation of the driving SAW. All details of these experimental studies will be reported in the paper.

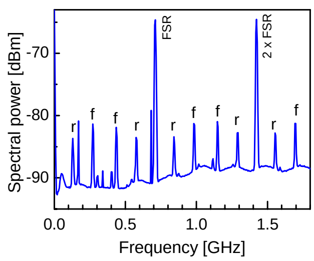

Figure 3: RF-spectrum of the output from a Michelson interferometer with FSF laser as input source.

[1] S. Reza, H. Herrmann, V. Quiring, R. Ricken, K. Schäfer, H. Suche, and W. Sohler, "Frequency Shifted Feedback Ti:Er:$LiNbO_3$ Waveguide Laser of Wide Tunability", *Proceedings of 11th European Conference on Integrated Optics (ECIO'03)*, 167–170, Prague, Czech Republic, April 2–4, 2003.