Integrated Frequency Shifted Feedback (FSF) Laser for Optical Frequency Domain Ranging (OFDR)

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The integrated, wavelength tuneable Frequency Shifted Feedback (FSF) laser, recently developed [1], is further improved and applied for Optical Frequency Domain Ranging (OFDR). The laser is fabricated in an Erbium-diffusion-doped Lithium Niobate substrate and has Titanium-diffused optical channel waveguides (Fig. 1). An acousto-optical (AO) filter inside the laser cavity is used as wavelength selective element and as frequency shifter simultaneously. The laser resonator is formed by dielectric mirrors deposited directly on the polished waveguide end faces. During each round trip the laser field undergoes two polarization conversions with two frequency shifts in the same direction. So the total frequency shift ($\nu_{FS}$) per round trip is equal to twice the frequency of the surface acoustic wave (SAW) driving the AO mode converter/filter. The FSF laser output consists of a comb of frequency chirped optical waves under a broad spectral envelope (Fig. 2). The components of the comb are separated by the free spectral range (FSR) of the laser cavity and they are strongly correlated in phase. Each is generated with a time interval equal to $1/\nu_{FS}$ and has a frequency chirp rate $\gamma = \nu_{FS}/\tau_{RT}$, where $\tau_{RT}$ is the round trip time in the cavity ($\tau_{RT} = 1/\text{FSR}$).

The integrated FSF laser has a cavity of 94.2 mm length resulting in a FSR of 711 MHz. To get lasing at 1560 nm wavelength, a SAW frequency ($\nu_{SAW}$) of 171.70 MHz is adjusted. The frequency chirp rate is $\gamma = 2\nu_{SAW} \times \text{FSR}$, with $m = 0, \pm 1, \pm 2, \pm 3, \ldots$, where $m$ is an integer termed “beat order” equal to the difference of the mode numbers of the comb components producing the beat signal. Fig. 3 shows as example for $2z = 29.5$ cm the RF spectrum of the resultant photodiode signal. The beat order $m$ is derived from the slope $d\nu_{FS}/d\nu_{SAW}$. The spatial resolution ($\Delta z$) is limited by the spectral width of the beat signal which is a function of $\nu_{chip}$ and $\gamma$. The theoretical limit of our laser is $\Delta z = 5$ mm in good agreement with the experimental results. Details of the measurement technique and further results will be presented in the talk. Moreover, the potential of this laser for long distance OFDR measurements with high resolution will be discussed.

![Figure 2: FSF laser spectra in time-frequency plane. Gradient in colour represents the amplitude variation. X and Y combs are from two branches of the interferometer arriving at the photodiode with a time delay $2z/c$.](image)

![Figure 3: RF spectrum of the photodiode signal for $2z=29.5$ cm.](image)
