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Erbium-Doped Lithium Niobate Waveguide Lasers

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In the last few years a whole family of diode-pumped Ti:Er:$LiNbO_3$ waveguide lasers has been developed emitting at wavelengths around 1550nm [1]. As they can be monolithically combined with a variety of further active and passive devices on the same substrate advanced integrated optical devices and circuits can be fabricated for a variety of applications in optical communications, sensing, signal-processing, and measurement techniques.

The enabling technology is diffusion-doping of the $LiNbO_3$ substrate resulting in a high quality laser-active surface layer [2]. It accepts optical waveguide fabrication by Ti-indiffusion, whereas proton exchange leads to a drastic quenching of the lifetime of excited Er-ions. The simplest Fabry-Perot type lasers are fabricated by depositing dielectric mirrors on the polished waveguide end faces to form the laser resonator. Its spectral properties together with the gain spectrum of Er:$LiNbO_3$ determine the emission wavelength. All the devices are pumped by a 1480nm fiber-pigtailed laser diode delivering up to 150mW output power.

Due to the excellent electro-optical, acousto-optical and nonlinear properties of the substrate waveguide lasers of higher functionality can be developed. By incorporating a phase- or amplitude modulator in the cavity several types of modelocked lasers have been realized. Using a coupled cavity concept an excellent supermode stabilization has been achieved with the following results: below 10ps pulse width up to nearly 20GHz repetition rate, side mode suppression ratio of more than 55dB, up to 10mW average power, extremely low amplitude and phase noise.

An intracavity Mach-Zehnder interferometer with a high extinction ratio (>25dB) was the key component of a Q-switched laser with output pulses of a halfwidth down to 2.1ns and up to 2.5kW peak power at 1kHz repetition rate.

By incorporating an acousto-optical filter a tunable laser has been developed with a tuning range $1530nm < \lambda < 1575nm$. The filter consists of two acousto-optical polarization converters in series between integrated polarizers. The converters are operated by guide surface acoustic waves of a frequency of about 170MHz; the tuning slope is about 8nm/MHz.

By replacing one of the dielectric mirrors by a holographically written, fixed photorefractive grating a narrow linewidth distributed Bragg reflector (DBR-) laser has been fabricated yielding an output power of up to 5mW.

Moreover, Ti:Er:$LiNbO_3$ waveguides can be periodically poled by electric field assisted ferroelectricdomain inversion. This enabled the development of a quasi-phase-matched self-frequency doubling laser with simultaneous emission at the fundamental wavelength 1531nm and at the second harmonic wavelength 765nm. A similar approach will lead to an intracavity pumped mid-infrared optical parametric oscillator.

References:

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*[2] I. Baumann et al., „Erbium incorporation in $LiNbO_3$ by diffusion-doping", Applied Physics A, **A64**, 33 (1997)*