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Self-Pulsing Ti:Er:LiNbO$_3$ Waveguide Laser

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During the last years a whole family of Er-doped LiNbO$_3$ (LN) waveguide lasers of excellent quality has been developed emitting in the wavelength range 1530 nm < λ < 1603 nm. Among them are free running lasers of the Fabry Pérot type, Distributed Bragg Reflector- (DBR-) lasers, self-frequency doubling devices, acousto-optically tuneable lasers, electro-optically Q-switched and harmonically mode-locked lasers [1]. Besides low frequency relaxation oscillations, which can be well suppressed, no self-pulsation phenomena have been published.

The self-pulsing laser reported here was fabricated in a 92 mm long Er-diffusion doped Z-cut LN substrate with a surface concentration of about 1.24 x 10^{20} cm^{-3} and a diffusion depth of 8.4 µm. Ti stripes of 7 µm width were indiffused to define single mode waveguides for the 1550 nm wavelength range. The laser cavity was formed by two dielectric multilayer mirrors, one of them vacuum-deposited on the input/output face of the Ti:Er:LN waveguide. This mirror has a high reflectivity (HR > 80 %) at wavelengths > 1550 nm, but a high transmission (T > 80 %) at the 1480 nm (pump) wavelength. The second mirror has a broadband characteristic of high reflectivity (R=97%) at both, pump and laser wavelengths; it was kept in contact with the other end face enabling double-pass pumping. Gold plated electrodes of 10 mm length fabricated near both waveguide ends enable a push-pull phase modulation to minimize spatial hole burning effects in the laser cavity.

The experimental set up to investigate the laser is shown in Fig. 1. A fibre wavelength division multiplexer (WDM) is butt coupled to the coated end face of the waveguide to couple the pump light into the cavity and to extract the laser output. A fibre grating stabilized laser diode was used as pump source of up to 200 mW power at 1480 nm wavelength. By a feedback control of the pump power, relaxation oscillations were suppressed.

The laser was operated with TE-polarized pump radiation yielding somewhat higher gain than with TM-pumping. A threshold of 37 mW of incident pump power was observed, corresponding to about 15 mW of coupled power. The laser emission was TE-polarized with a center wavelength at 1611.8 nm. This long emission wavelength is reported for the first time; it is determined by the low cavity losses (0.04 dB/cm waveguide propagation losses) in combination with a four-level laser scheme for the relevant transition.

Measuring the laser output with a high bandwidth sampling scope, surprisingly revealed that short pulses of a repetition rate of 720 MHz are emitted, corresponding to the free spectral range of the cavity (Fig. 1, middle). To determine better the structure and halfwidth of the pulses, they were analyzed with an optical autocorrelator; the result shows that at least two pulses (separated by 42 ps) are emitted during every round trip time. However, the large pedestal of the auto-correlation trace suggests that the phase correlation between the oscillating modes and their relative amplitudes are not stable in time. This conclusion is supported by the emission spectrum which strongly alters with time (an example is given in Fig. 1, right). A coarse and a fine structure are always observed confirming qualitatively the time domain result of a double pulse emission every roundtrip. Also the radio frequency spectrum of the laser output confirms that a large number of cavity modes are oscillating (Fig. 1, right).

A possible explanation for such pulsations might be the Risken-Nummedal-Graham-Haken instability [2,3]. An analysis of experimental data to confirm this hypothesis is in progress.

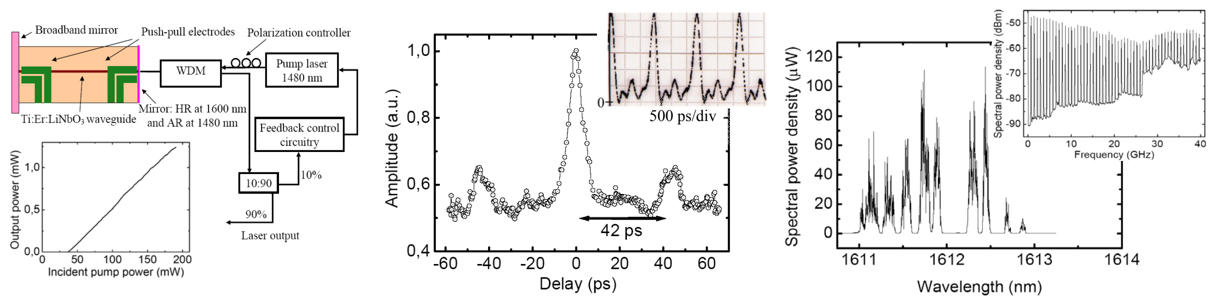

Fig. 1 Left: Experimental set up with laser power characteristic as inset. Middle: Pulse analysis in the time domain: autocorrelator and sampling scope (inset) results. Right: Pulse analysis in the wavelength domain: optical and radio frequency (inset) spectra of the output.

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