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Towards on-chip ultrafast pulse amplification

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Amplification of ultrafast optical signals is key to a large number of applications in photonics. While ultashort pulse amplification is well established in optical gain fibers, it is challenging to achieve in photonic-chip integrated waveguides. Recently, several integrated (quasi-)continuous-wave amplifiers have been demonstrated, based on rare-earth, heterogeneous semiconductor integration or nonlinear parametric gain [1-4]. On-chip amplification of ultrafast pulses, however, remains challenging due to the inherently small mode area and high-optical nonlinearity in integrated waveguides.

Here, we present our recent work towards an on-chip ultrafast amplifier, leveraging large mode-area gain waveguides with tailored group-velocity dispersion (GVD). The amplifier structure combines silicon nitride (Si_3N_4) waveguides with a radio-frequency sputtered thulium-doped alumina gain layer (Tm^{3+}: Al_2O_3), providing large gain bandwidth (1650nm-2000nm) and supporting sub-100 fs pulses. By designing the dimension of the Si_3N_4 waveguide, the waveguide's GVD, the mode confinement, and its overlap with the gain layer is tailored to achieve stable pulse propagation [5], low-loss waveguide bends and large optical gain (Fig. 1a-d) [6,7]. Fig. 1e shows broadband amplification with 10 dB net gain of a pulsed input signal (1820 nm center wavelength, 0.1 mW) in an amplifier characterized by a mode cross-section $> 10\ \mu m^2$ in the gain section and an estimated Tm^{3+} concentration of $4.0 \times 10^{20} cm^{-3}$. The pump power at 1610 nm is 240 mW. These results, open a pathway towards on-chip amplification of ultrashort pulses, with potential implications for spectroscopy, ranging or nonlinear mid-infrared light generation [8] in a chip-scale integrated photonic setting.

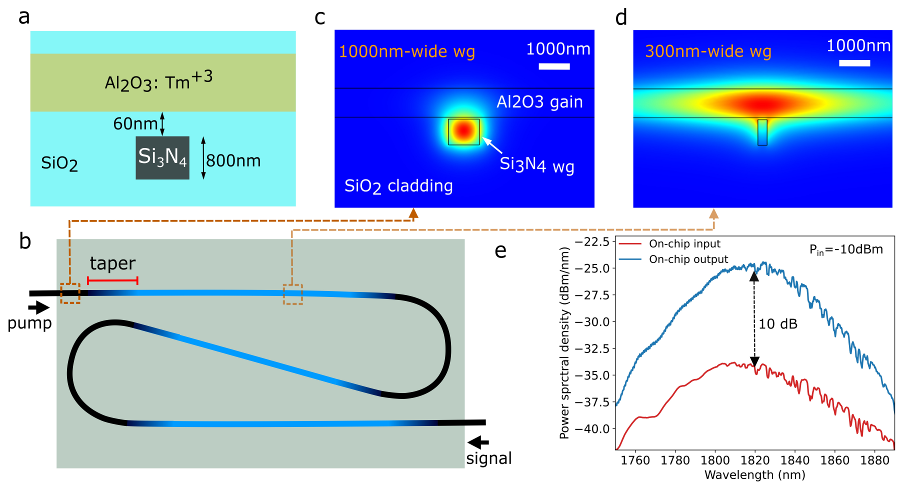

Fig. 1 (a) Amplifier waveguide cross-section (b) Illustration of chip-layout. Black: wide Si_3N_4 waveguide with strong mode confinement. Blue sections: narrow Si_3N_4 waveguide with weak mode confinement and large mode-overlap with the Tm^{3+}: Al_2O_3 gain layer. (c) and (d) TE mode profiles of a 1830 nm signal for 1000nm and 300nm-wide Si_3N_4waveguides, respectively. (e) Optical spectra of the input and output signals.

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