Enhancement and shape control of weak molecular absorption signal with chirped-pulse mid-IR lasers

***E. Sorokin*[1]*, N. Tolstik*[2]*, I. Sorokina*[2]**

1. Photonics institute, TU Wien - Vienna University of Technology, Vienna, Austria

2. Department of Physics, The Norwegian University of Science and Technology, Trondheim, Norway

Detection of weak narrowband absorption by molecular lines is usually a topic of linear-optical technology. In this paper we demonstrate nonlinear-optical enhancement and shape control of atmospheric absortion lines using a broadband ultrashort-pulse oscillator and nonlinear fiber propagation. The absorption signal is generated inside the passively mode-locked mid-IR Cr:ZnS laser. The nonlinear interaction with the broadband ps-long pulse causes the narrow-band ns-long absorption signal to acquire a 90° phase shift with respect to the pulse [1]. The signature of such an absorber on the output spectrum is a dispersion-like modulation, which can be much stronger than absorption modulation itself. This effect has been experimentally observed using the atmospheric water vapour absorption lines around 2.5 μm in Cr:ZnSe laser [1, 2]. Additional modulation increase has been predicted to occur near the spectrum edge if the laser is operating in a chirped-pulse (dissipative soliton) regime.

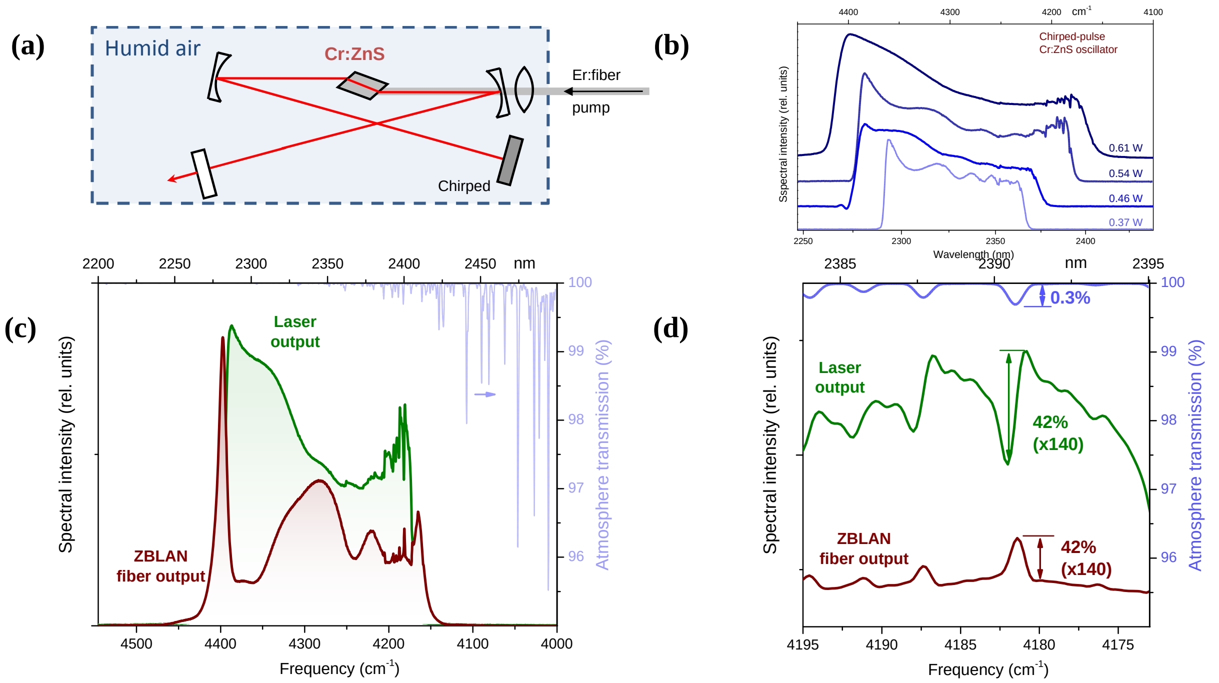

Fig. 1 Experimental setup (a) and spectrum control by output power tining (b). Overview (c) and expanded section near 2390 nm (d) of the laser output spectrum (green) and after 2 m ZBLAN fiber propagation (dark red). Light blue curve shows atmospheric transmission for the same cavity length and spectral resolution.

The experimental setup uses a Cr:ZnS oscillator at 2.4 μm (Fig. 1a). In the chirped-pulse regime, the spectrum acquires typical sharp edges, position of which depends on the output power (Fig. 1b). This allows tuning of the absorption edges to the required spectral region. Near the spectrum edge, the molecular absorption signal is strongly enhanced by a factor of 140 in our case with respect to the linear absorption over the resonator cavity length. Furthermore, the shape of the absorption signal can be changed from the dispersion-like to peak-like signatures by simple propagating in a nonlinear fiber. We use 2 m piece of a commercial single-mode ZBLAN fibe, which has anomalous dispersion in this wavelength range. If the fiber is sufficiently long to allow pulse compression, the propagation becomes nonlinear resulting in additional phase delay between the pulse and the narrow-band signal, which can be finely tuned by launched energy to become e.g. a conventional peak-like signal. We observe signal enhancement by a factor of 140 for weak water vapour absorption lines. Since the position of the spectrum edge can be reliably controlled, this demonstration opens a way to practical applications of intracavity soliton spectroscopy.

References

[1] V.Kalashnikov, E. Sorokin, "Soliton absorption spectroscopy", Phys. Rev. A **81**, 033840 (2010)

[2] V. Kalashnikov, E. Sorokin, and I. T. Sorokina, "Chirped dissipative soliton absorption specgroscopy", Opt. Express **19**, 17480 (2011).