Towards a Monolithic, Multi-gigahertz Mode-locked Ti:Sa Laser

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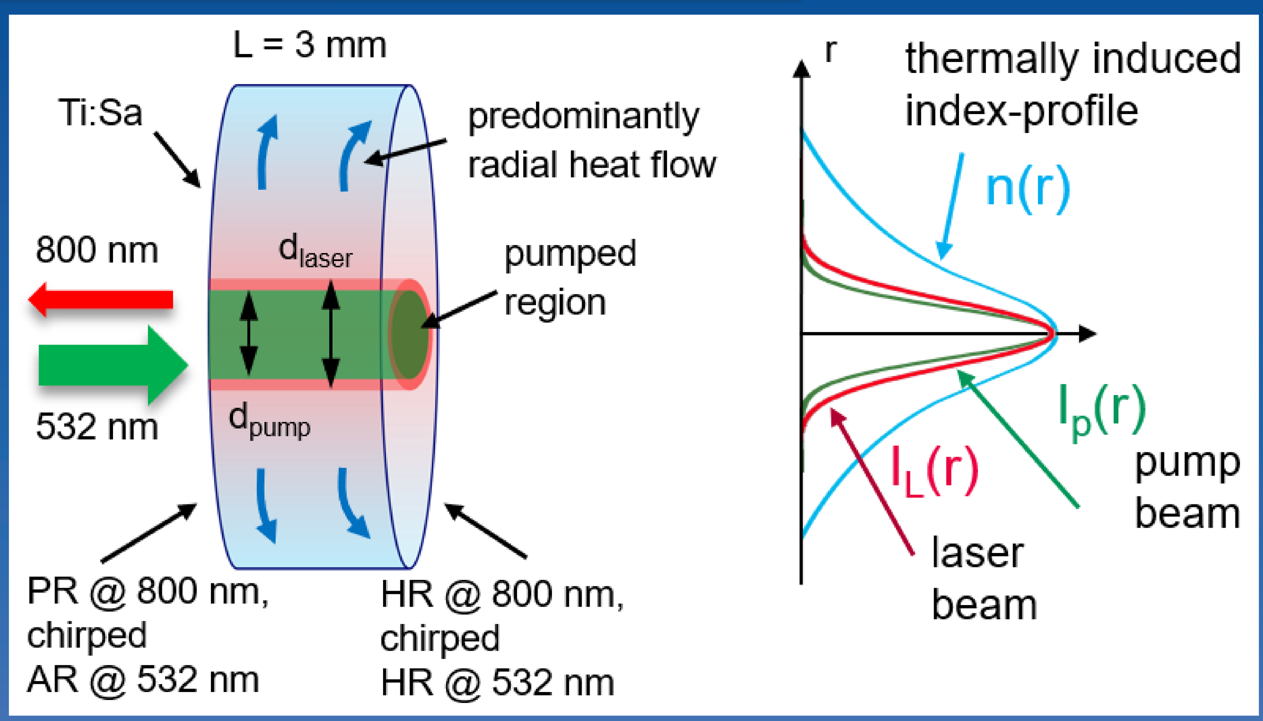
Abstract

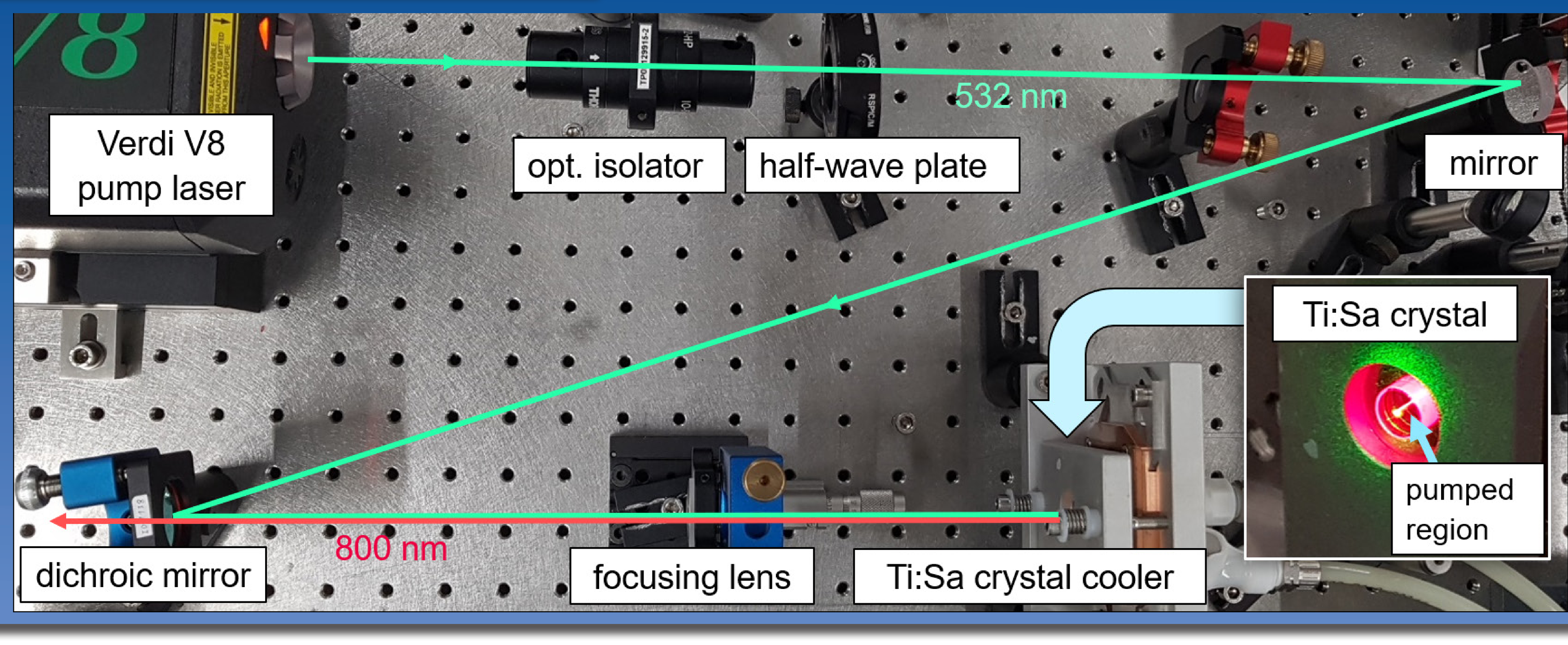
We demonstrate a design for monolithic, soft-aperture Kerr-lens mode-locked Ti:Sa lasers with repetition rates between 30 GHz and 300 GHz. Both optical surfaces of the Ti:Sa crystal are planar and coated with dispersion-compensating coatings. The laser becomes stable by thermal lensing due to absorption of the pump beam. Due to the large bandwidth of Ti:Sa, hundreds of longitudinal modes can be sustained even with mode spacings above 100 GHz. (For mode-locked lasers the mode spacing equals the repetition rate). First experiments did not show mode-locking but cw laser operation with power fluctuations of less than 0.04% rms. The autocorrelation falsely shows a pulse which can be attributed to white light interference. Possible obstacles for mode locking in our laser are spatial-hole burning (SHB) and a standing-wave of the pump beam causing undesired frequency pulling.

Monolithic Laser Design

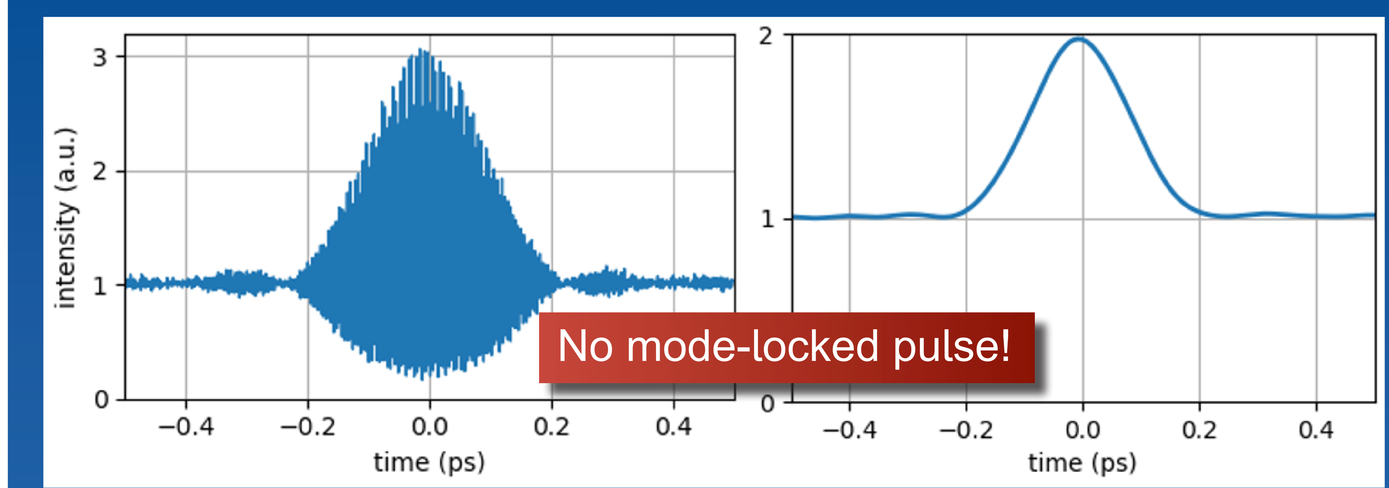


- Plane-plane resonator with thermally induced index-profile
- With proper pump spot size, pump beam and Ti:Sa laser beam both become eigenmodes of the gradient index medium with constant beam diameters while propagating through the Ti:Sa.
- Mode-locking mechanism: Soft aperture KLM

Experimental Setup



Autocorrelation



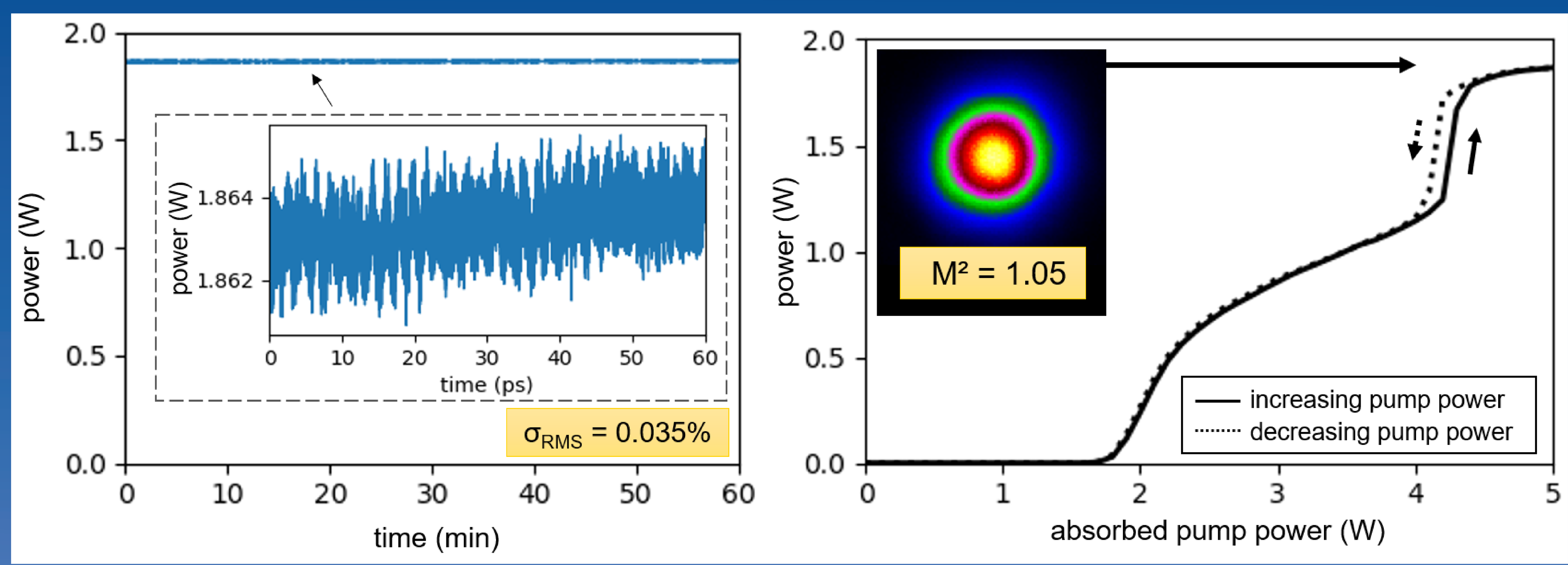
Interferometric (left) and intensity autocorrelation (right) measured with the pulseCheck autocorrelator from APE.

- Contrast of interferometric autocorrelation is 3:1 instead of 8:1.
- The peak-to-background ratio in the intensity autocorrelation is 2:1, but for mode-locked pulses the intensity AC-trace should be background-free.
- Pulse stretching using grating pairs providing up to 10^6 fs² did not change the autocorrelation trace.

► **No mode-locked pulses, but white light interference of mutually incoherent longitudinal modes.**

► **Duration of AC-trace (130 fs) is equal to coherence time of cw laser beam.**

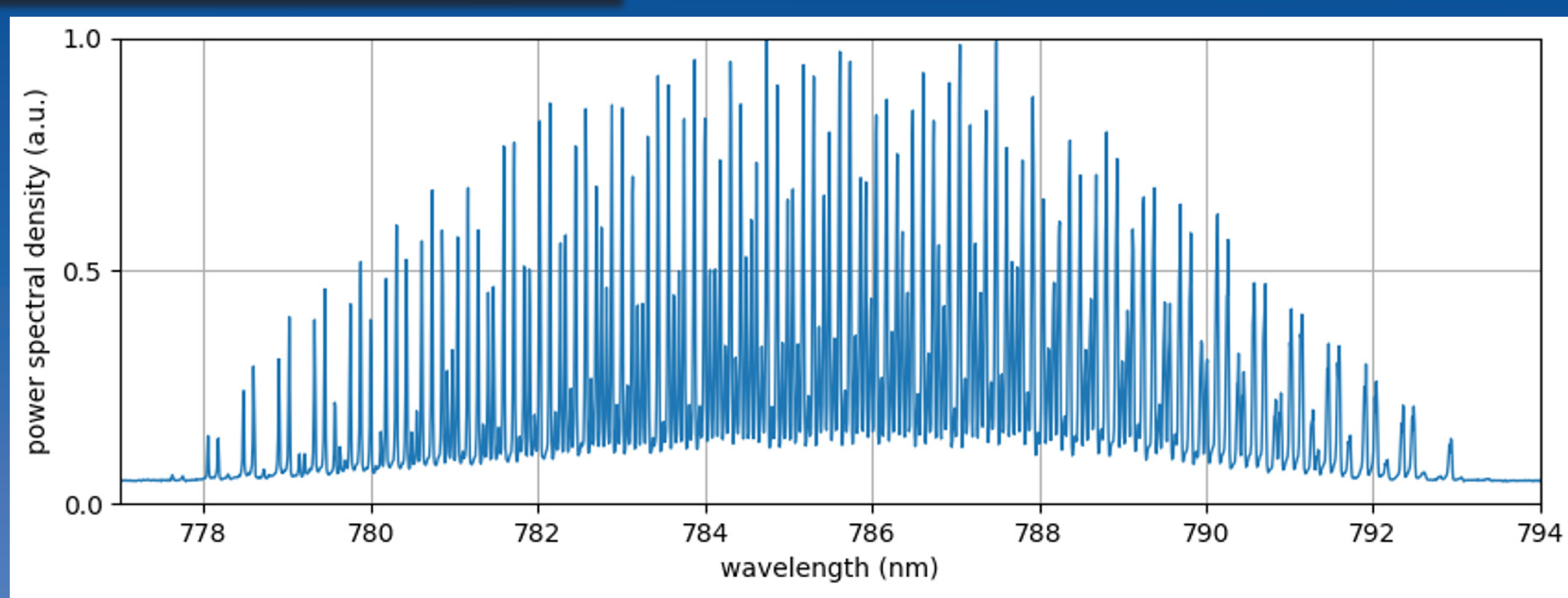
Power and M²



Left: Ti:Sa laser is stable with an rms power fluctuation of only $3.5 \cdot 10^{-4}$ in one hour.

Right: Output power vs. absorbed pump power shows nonlinear increase and hysteresis because the Ti:Sa acts as an etalon for the pump beam. The inset shows the beam profile at maximum output power.

Spectrum



Optical spectrum of our Ti:Sa laser, measured with a spectrometer with a proven spectral resolution of 30 pm.

Conclusion and Outlook

- Spectrum is unusually broad (15 nm) for a cw laser due to enhanced SHB caused by an extreme case of gain-at-the-end. This leads to increased requirements for the flatness of the group delay dispersion curve of the coatings which may not have been fulfilled.
- Standing wave of the pump beam creates a gain grating causing frequency pulling. For mode locking, frequency pulling is detrimental because mode locking requires a constant frequency difference between longitudinal modes.

► **Currently, 1 mm crystals are being coated which have a flatter group delay dispersion curve compared to the 3 mm crystal.**

► **Another batch of Ti:Sa crystals will be coated with AR-coating for the pump beam on both surfaces to prevent the standing wave.**

► **Experiments are planned to understand the influence of SHB and frequency pulling on mode-locked lasers**

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