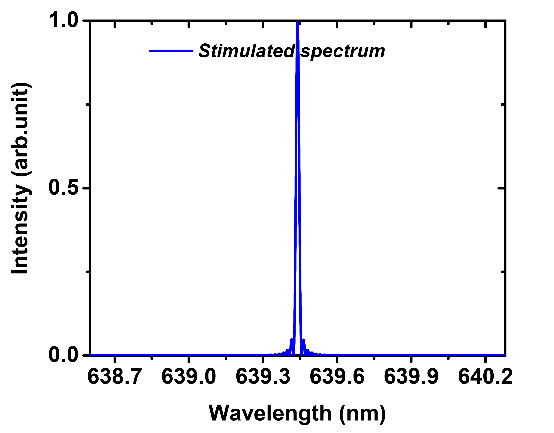
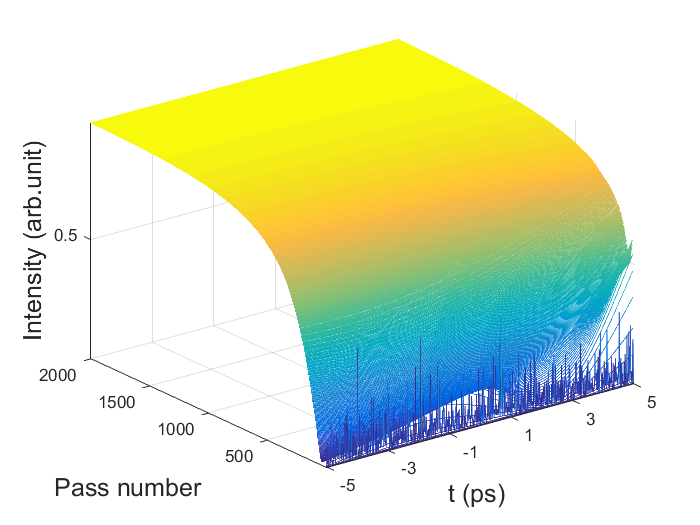


**(b)**

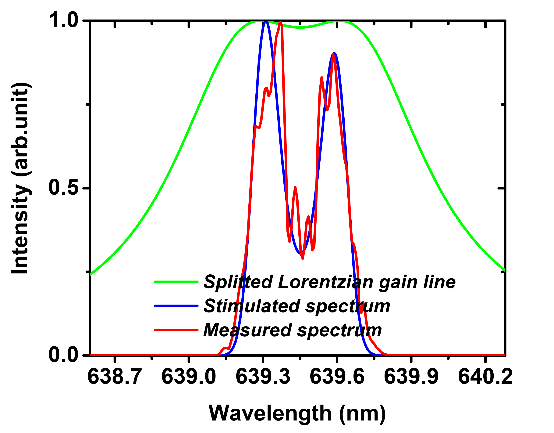
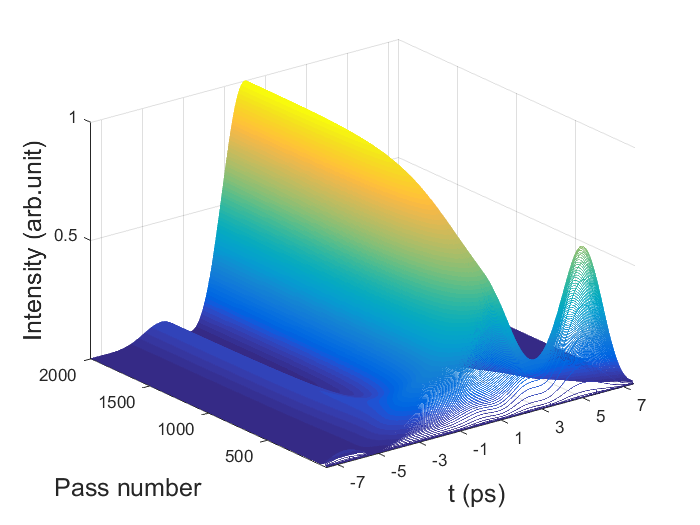
**(a)**



**(d)**

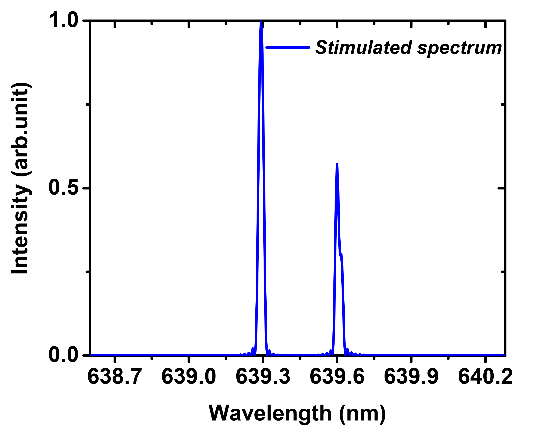
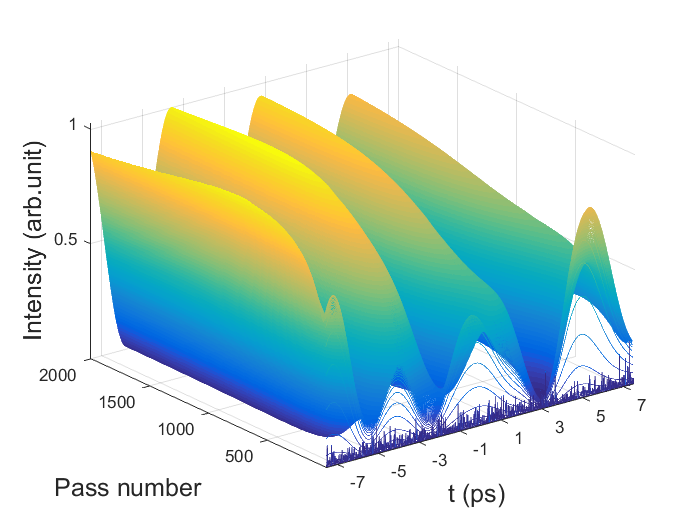
**(c)**

Fig 6. Pulse evolution in the cavity



**(a)**

**(b)**



**(d)**

**(c)**

Fig 7.

The model of the self-started Kerr-lens mode-locking procedure consists of a laser gain media and an intensity modulator. The laser gain media can be thought of as an amplifier that has a gain line shape, which can be modeled by a frequency filter. As for the amplifier, the saturation effect should also be taken into account and its effect on the gain factor *g* is given as

,(1)

Where *g*ss is the small-signal gain factor, *P* is the signal power, *P*sat is the saturation power. With regard to the gain line shape, Pr3+:YLF laser is solid-state laser with a gain-line shape corresponds to Lorentzian profile which belongs to homogeneous broadening [2016, Li Qing-Song]. The gain coefficient can be expressed as

,(2)

among which *ν*0 is the central frequency and *Δν* is Full Width at Half Maximum (FWHM) of the laser gain-line shape. For the 3P0→3F2 transition line at 640 nm, *Δλ* is 0.69 nm, leading to a *Δν* of 506.2 GHz. Owing to the spatial-temporal narrowing of the signal by Kerr-lensing effects of the gain media, the intensity of the intracavity laser is modulated passively. The model of the intensity modulation can be briefly thought of as a Gaussian profile in the time domain and be written as

,(3)

where *t*0 is the reference time, and *Δt* is the FWHM of the modulation signal.

After the laser crystal, the signal propagates in the atmosphere, where it experiences no chromatic dispersion or nonlinear effect, and is governed by the linear differential equation

,(4)

where *L* is the cavity round-trip loss, and can be solved by using the finite element method. After one round trip, the signal is fed in the gain media again and completes another round trip. The process is repeated until equilibrium is reached.

The stimulation results that coincides with the FWHM of the measured spectrum depicted in Figure 3 (b), which was 0.39 nm, is depicted in Figure 6(a) and (b). In this stimulation, the FWHM of the modulation signal *Δt* was tuned to 3.5 ps so that the FWHM of the calculated spectrum was also 0.39 nm. As is shown in Figure 6(a), a stable optical pulse was obtained with a pulse width of 1.5 ps, leading to a time-bandwidth product of 0.427, meaning a transform limited result. As a comparison, stimulations with no intensity modulation was also carried out, the response in time domain and the stimulated wavelength are illustrated in Figure 1(c) and (d), respectively. As can be seen, the result in the time domain becomes a direct current signal, and the FWHM of the stimulated wavelength was shortened, corresponding to a continuous-wave operation state.

It is interesting to note that, in our experiments, laser spectrums with a relatively big dip in the center shown as the red line in Figure 2(b) were sometimes captured meanwhile the laser was mode-locked. The possible reason for the dip in the laser spectrum was frequency shift caused by the gain-line splitting [93, Zhijiang Wang].

[2016, Li Qing-Song]. “The effect of the depth of single longitudinal mode modulation in Q-switching pre-Pr3+:YLF laser”

[93, Zhijiang Wang]. Novel self-mode-locking mechanism in narrow-band lasers