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 [wolfram]

 (1)

where  is the central frequency and  is full width at half-maximum of the laser gain-line shape.

By introducing a frequency shift of the Stark splitting  from the unperturbed frequency induced by the intra-cavity laser field, Eq. (1) can be written as

(2)

According to the rough self-mode-locking criterion for solid-state lasers [1992, Zhijiang Wang], self-mode-locking pulses can occur when 

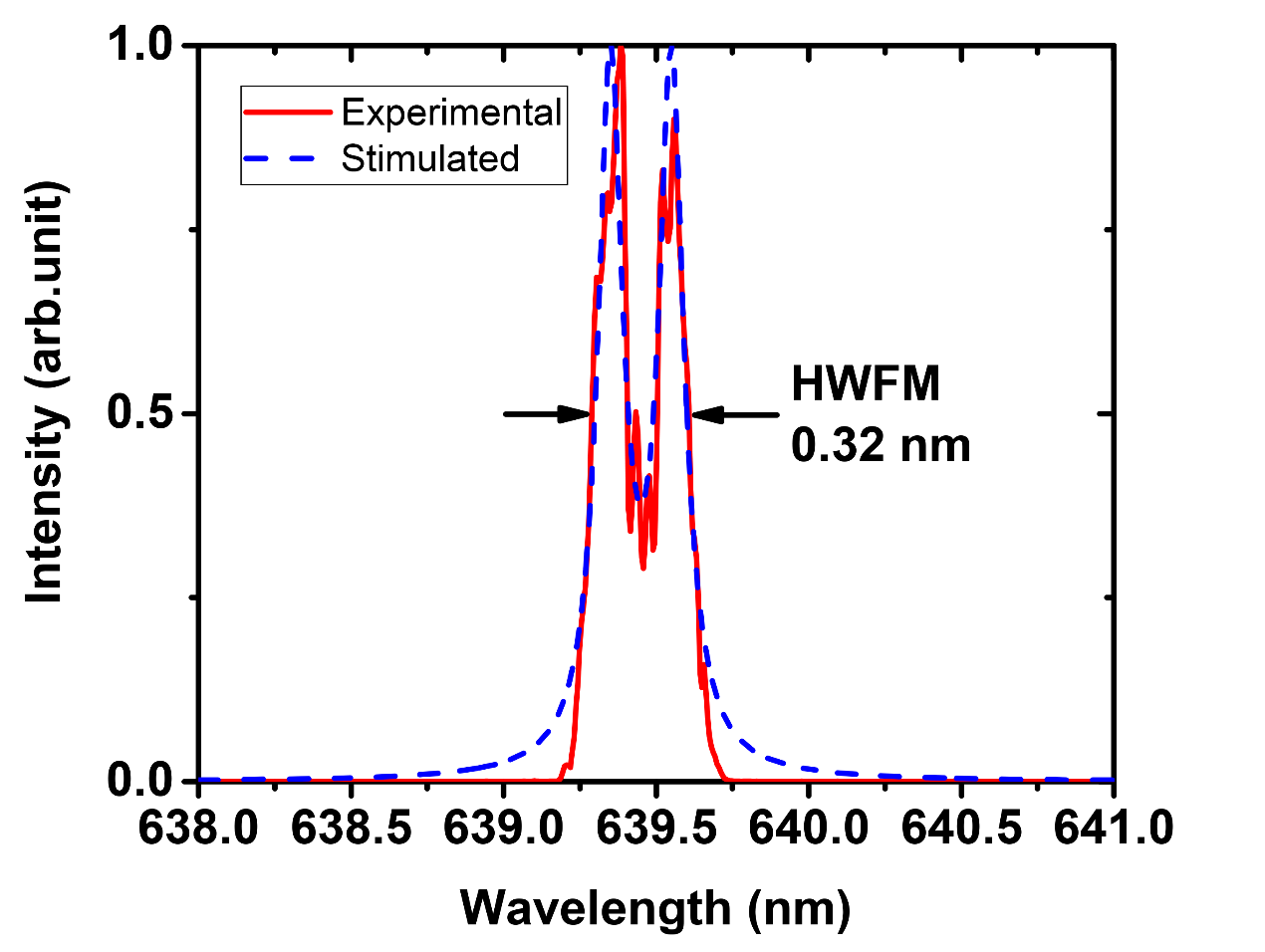


Figure 1. Measured laser spectrum (red line) and the fitting curve of the gain-line shape (blue dashed line) when Δ*ωs*=Δ*ωg* at the wavelength of 639 nm.

As is recorded in Fig. 1, the stark splitting gain-line shape when Δ*ωs*=Δ*ωg*, which satisfies the rough self-mode-locking criterion, coincides well with the measured laser spectrum. The subtle difference between the stimulated stark splitting gain-line shape shown as the blue-dashed line and the measured spectral shape of output pulses depicted as the red line might be attributed to the fact that stark effect should be considered dynamically, thus forming a gain-line shape with several small dips.

Theocratically, from the laser spectrum, we can easily obtain the corresponding time domain pulse train by just a simple Fourier transform. But the resolution of the measured spectrum, which is 0.08 nm, is not sufficient enough to support the calculation. It is even much larger than the mode interval of the longitudinal mode of the cavity, which is measured to be 93 MHz, corresponding to a wavelength interval of 1.27×10-4 nm. But with the fitted line-shape, we can simply increase the resolution of the data as much as we want. The problem is solved.

Considering the effect of the laser intensity to the gain line profile, the gain coefficient can be written as,

,(3)

among which *I* is the intensity of the emitting laser and *Is* is the saturation intensity of the laser medium. For mode-locked ultra-fast pulses, suppose that little energy could be obtained by the pulses on a single pass, *Is* could be approximately expressed as [1992, Zhijiang Wang],

,(4)

Where *Es* is the saturation energy, *τ*ext is the lifetime of the excited state, τ*p* is the pulse width and L the cavity length. By substituting Eq. (2) into Eq. (3),

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

[wolfram]. <http://scienceworld.wolfram.com/physics/LorentzianLineshape.html>

[1992, Zhijiang Wang]. “Novel self-mode-locking mechanism in narrow-band lasers”

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