Generating Picosecond Pulses from Mid-Infrared Fiber Lasers Using Frequency-Shifted Feedback

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Ultrafast mode-locked fiber lasers in the near infrared have enabled a host of key applications in a variety of fields such as medicine and defense. In recent years there has been significant interest in pushing the emission wavelength of these fiber laser systems to the mid infrared (MIR 3 - 5 µm) due to the presence of strong molecular absorption features in this spectral range. Various techniques to achieve this have been demonstrated, with a majority of the work focused on implementation of loss modulation via real saturable absorbers. While this has been successful in generating picosecond pulses in the mid-infrared [1], commercial availability of absorbers is currently limited, and alternatives such as nanomaterials (graphene, black phosphorous) raise questions regarding long-term stability. Virtual absorbers based on nonlinear polarization evolution have shown comparatively superior performance in terms of pulse duration [2] but this method is highly sensitive to small environmental perturbations.

In this work we will present recent efforts to offer an alternative method of 'mode-locking' using frequency-shifted feedback (FSF) [3,4]. The method requires a frequency shifting element in the cavity, which in this case is an acousto-optic filter or modulator. Initial efforts are based on a dysprosium-doped ZBLAN fiber laser pumped with an Er:ZBLAN fiber laser (Fig. 1a). An acousto-optic tunable filter (AOTF) provides the requisite frequency shift and also a means of tuning the emission wavelength. The broad gain bandwith of dysprosium allows this system to be tuned over a range of 330 nm (Fig. 1b) with a pulse duration that remains consistent at 33 ps.

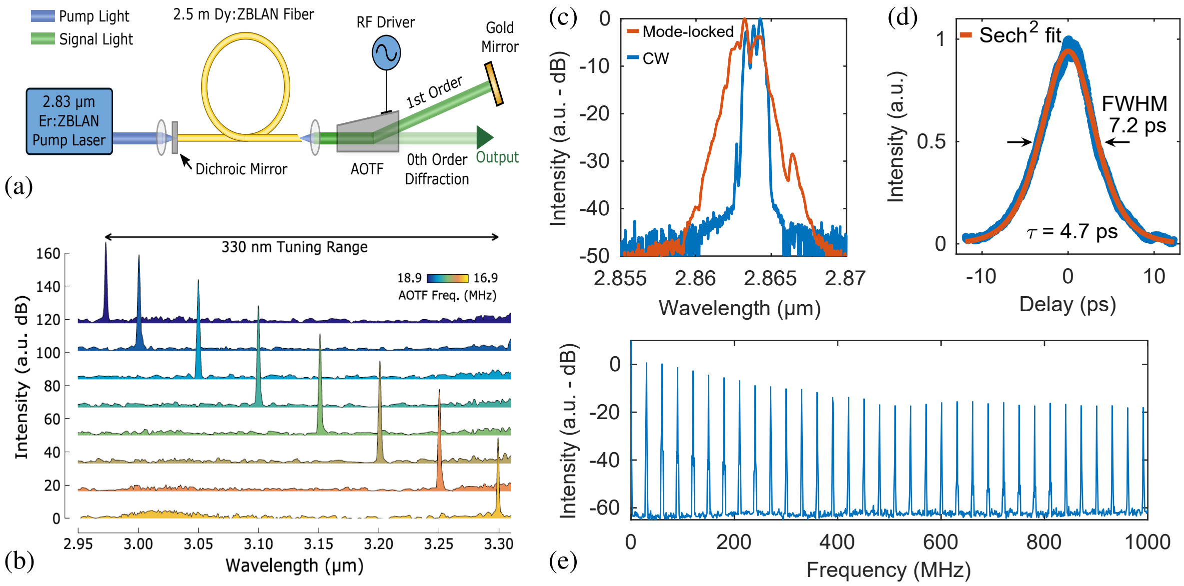

Fig. 1 a) dysprosium FSF cavity; b) tuning range of pulsed output for the Dy system; holmium-doped system performance: c) optical spectrum exhibiting broadening; d) autocorrelation trace with deconvolved pulse width of 4.7 ps; e) RF photodiode signal with multiple harmonics of the cavity round trip time.

Pulse formation dynamics are investigated numerically and will be presented with consideration to the various parameters that impact realized pulse duration. Of these it will be shown that a filtering effect is necessary in addition to the frequency shifting, with the AOTF providing this in the dysprosium case. Filter bandwidth is shown to in part dictate pulse duration, with a wider filter supporting shorter pulses. To investigate this we replace the dysprosium cavity with a similar holmium-doped system which replaces the AOTF with a simple acousto-optic modulator (AOM). The broader acceptance bandwidth of the AOM results in improved performance and a pulse duration of less than 5 ps (Fig.1 c-e), which surpasses the current record performance of mid-IR saturable absorber fiber lasers systems.

References

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