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A Broadly Tunable Ultrafast Diode-Pumped Ti:sapphire Laser

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Abstract: We report a diode-pumped ultrafast Ti:sapphire laser tunable over a 120 nm range. Sub-100 fs pulses are generated at a pulse repetition rate of 135 MHz with a maximum average output power of 430 mW.

Ultrafast diode-pumped Ti:sapphire lasers

Pump setup	Pump power	ML mechanism	Self-starting	Output Power	Pulse Duration	Tunability	Reference
2 × 452 nm	2 × 1 W	SESAM	Yes	101 mW	111 fs	No	[1]
2 × 520 nm	2 × 1 W 2 × 1.5 W	SESAM KLM	Yes No	200 mW 450 mW	68 fs 39 fs	No	[2]
2 × 450 nm	2 × 2.9 W	SESAM	Yes	460 mW	65 fs	No	[3]
2 × 450 nm	**2 × 3.5 W**	**SESAM KLM**	**Yes No**	**430 mW 158 mW**	**85 fs 38 fs**	**50 nm 120 nm**	**This work**

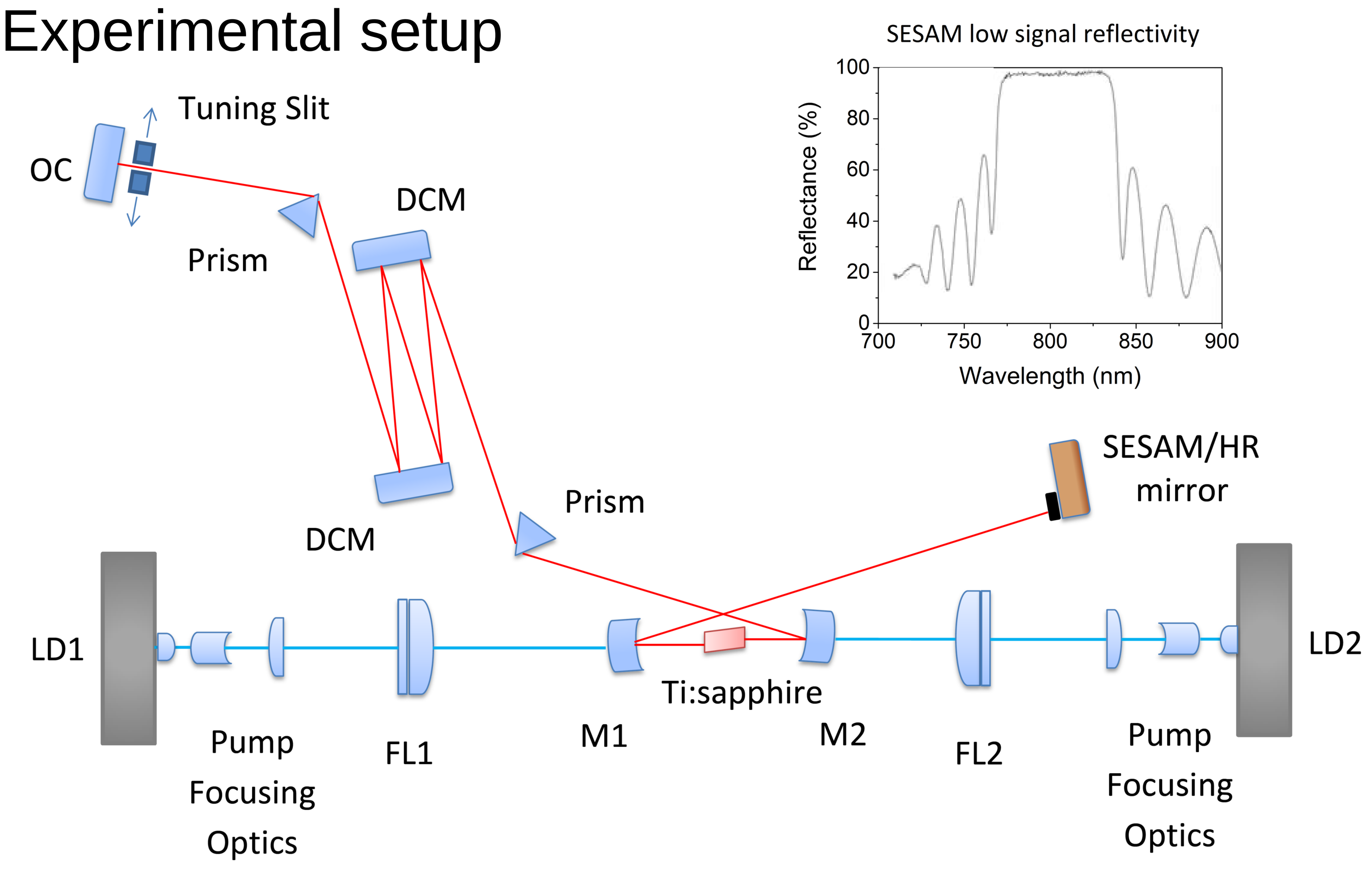
Mode-locking mechanisms

Here we report to the best of our knowledge the first broadly tunable diode-pumped ultrafast Ti:sapphire laser.

Laser experiments include two different mode-locking approaches: one using a semiconductor saturable absorber mirror (SESAM) and one using Kerr-lens mode-locking. The experimental setup was optimised for SESAM mode-locking by ensuring the cavity operated in the middle of stability zone II, thus creating a second cavity mode waist on the SESAM.

The same configuration was used for KLM by replacing the SESAM with a high reflector mirror and moving to the edge of cavity stability. KLM was then initiated by translating one of the folding mirrors towards the crystal.

Experimental setup



Laser experiments were performed with a Brewster-cut 4.8 mm long, 3 mm × 3 mm aperture Ti:sapphire crystal, FOM>200, Single pass absorption at 450 nm = 64%, $\alpha_{450\ nm} = 2.13\ cm^{-1}$.

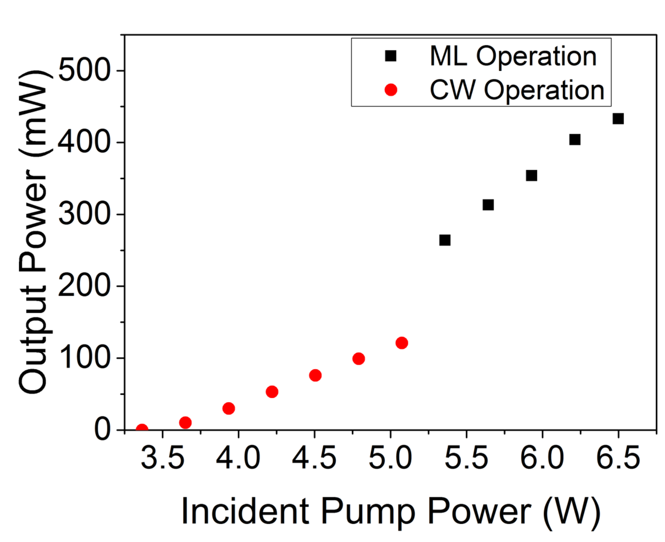
LD1 and LD2: 3.5 W, 450 nm, 28×1 μm emitting area.
Pump Focusing Optics: aspheric lens (f = 4.51 mm), concave cylindrical lens (f = -9.7 mm), convex cylindrical lens (f = 80 mm).
FL1: achromatic doublet lens (f = 100 mm).
FL2: achromatic doublet lens (f = 75 mm).

M1 and M2: dichroic high-reflecting folding mirrors, 75 mm ROC.
DCM: double chirped mirror, -120 fs^2 per bounce, GDD = -960 fs^2.
Prism: fused silica prism pair, tip-to-tip separation = 50 cm, 4 mm insertion, GDD = -677 fs^2.
Net cavity GDD: 556 fs^2 (crystal) - 960 fs^2 (DCM) - 667 fs^2 (prism pair) = -1087 fs^2.
OC: output coupler, 2% and 5% for SESAM setup, 1% for the KLM setup.
SESAM: distributed Bragg reflector structure with a GaAs quantum well, low-signal absorption was ~97.5% over the range of 775-840 nm, and non-saturable losses are <1%.

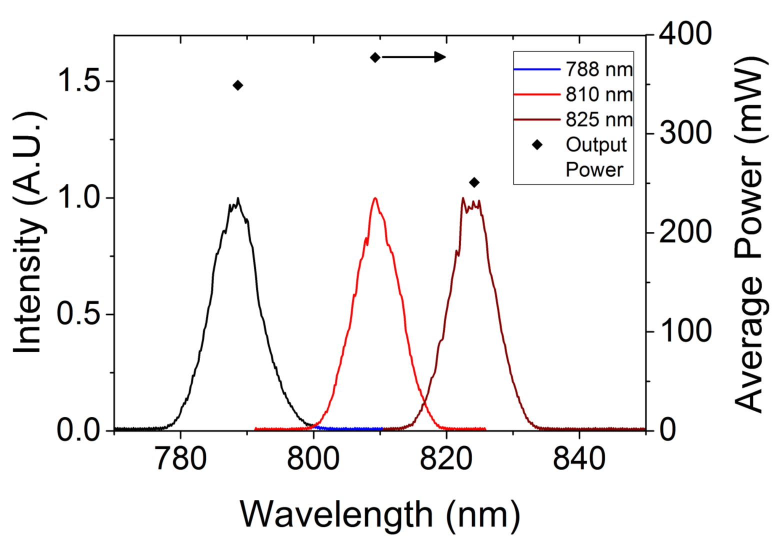
Pump beam waist radii: LD1: 39×13 μm, and LD2: 30×11 μm.
Laser cavity mode radii in the crystal: 29×16 μm.
Laser cavity mode radius on the SESAM: 85 μm.

SESAM mode-locking results

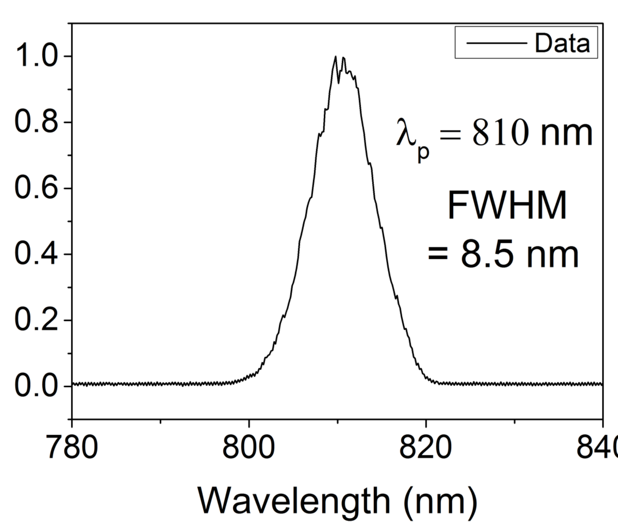
Input – output characteristics



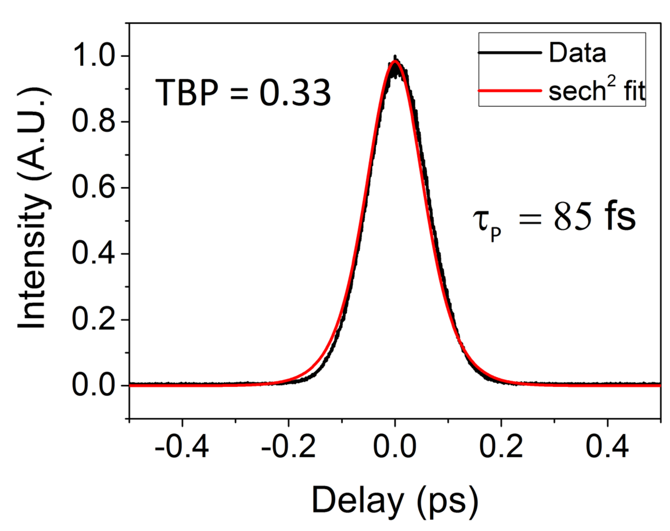
Tuning range



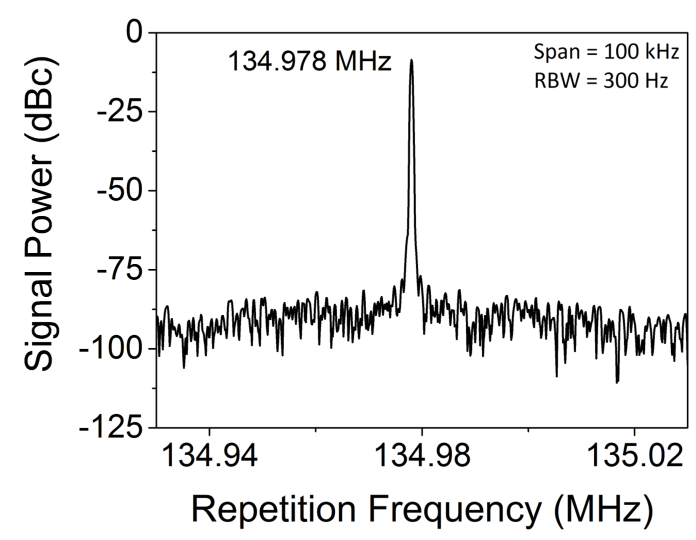
Optical spectrum



Corresponding autocorrelation

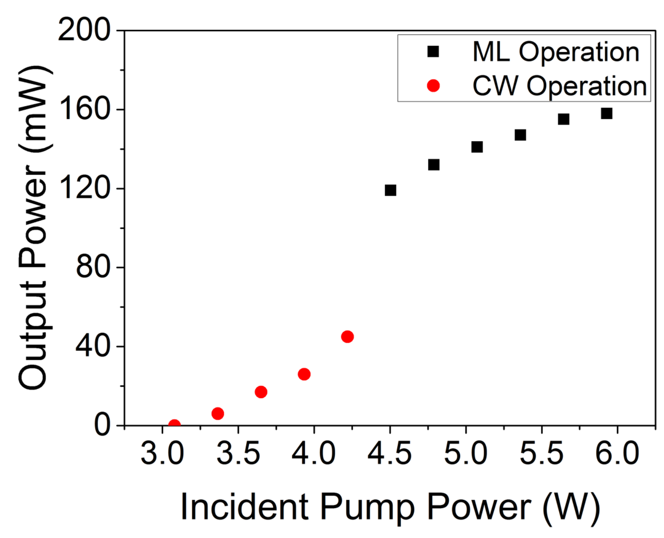


RF spectrum

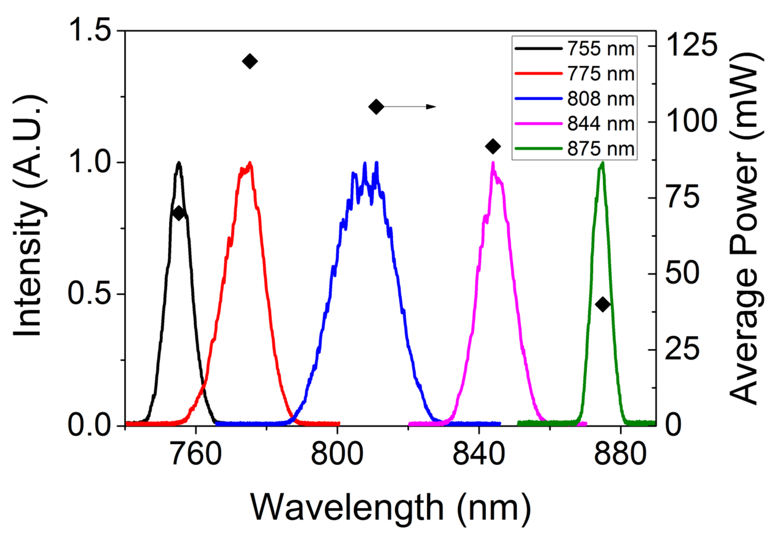


KLM results

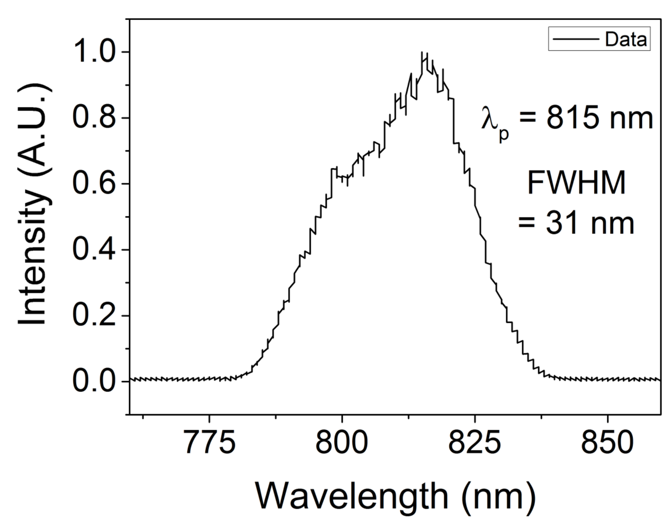
Input – output characteristics



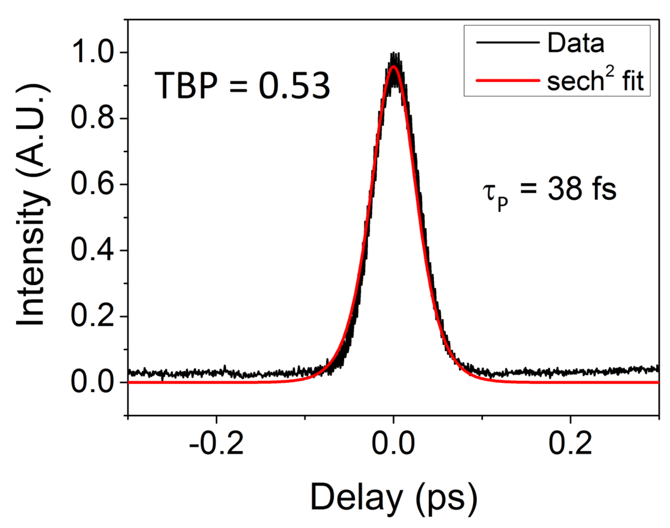
Tuning range



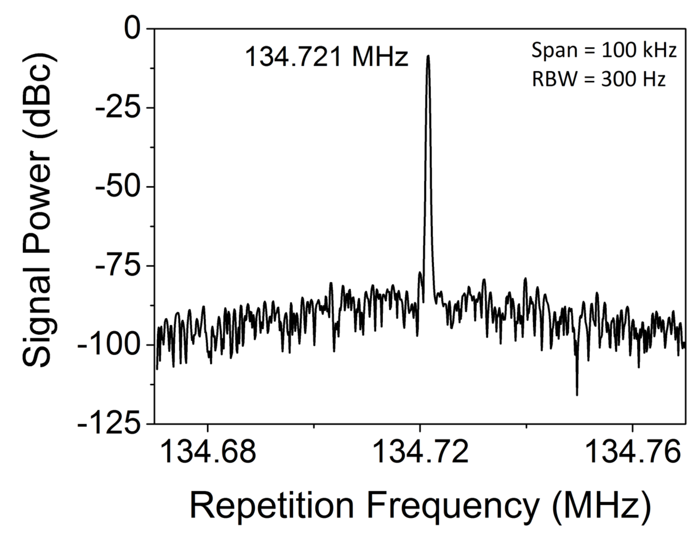
Optical spectrum



Corresponding autocorrelation



RF spectrum



Conclusion

In conclusion, we have demonstrated average output power as high as 430 mW, pulses as short as 85 fs and tunability as wide as 50 nm (2% OC) for the SESAM mode-locked Ti:sapphire laser. When operated in a KLM regime we were able to achieve a tuning range up to 120 nm, and output power as high as 158 mW.

In the case of the SESAM setup tunability was limited by the SESAM reflectivity range, rather than the gain bandwidth of Ti:sapphire. For the KLM configuration, work is underway to further optimise the current setup. Alternatively, wide bandwidth novel saturable absorber materials, such as graphene could be used as a mode-locking element.

References

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2. K. Gürel, V. J. Wittwer, M. Hoffmann, C. J. Saraceno, S. Hakobyan, B. Resan, A. Rohrbacher, K. Weingarten, S. Schilt, and T. Südmeyer, "Green-diode-pumped femtosecond Ti:Sapphire laser with up to 450 mW average power," Opt. Express 23, 30043-30048 (2015).
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