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High-Power Semiconductor Disk Lasers with Record-Short Pulse Durations

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Optically pumped ultrafast semiconductor disk lasers (SDLs), such as vertical external-cavity surface-emitting lasers (VECSELs, [1]) or modelocked integrated external-cavity surface-emitting lasers (MIXSELs, [2]), are compact high-power gigahertz lasers with excellent beam quality. Since the first demonstration of a semiconductor saturable absorber mirror (SESAM, [3]) modelocked VECSEL [4], the performance of SDLs has been constantly improved and shows a clear trend towards shorter pulse durations and higher output powers (Fig. 1a and b) [5]. The targeted applications of these ultrafast gigahertz SDLs benefit from pulse durations of hundreds of femtoseconds combined with high pulse peak power and comprise, among others, telecommunication, multiphoton imaging, and frequency metrology.

Here, we present our most recent VECSEL and MIXSEL structures emitting at 1 μm , which currently generate record-short pulse durations for their respective technologies (highlighted in Fig. 1a and b).

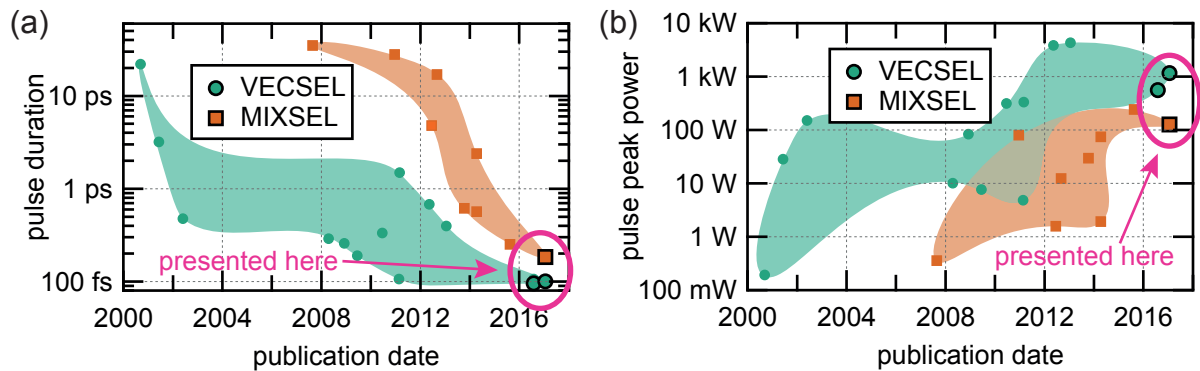


Fig. 1. Timeline of record (a) pulse duration and (b) pulse peak power results from SESAM-modelocked VECSELs (in green) and MIXSELs (in orange) in a logarithmic scale. The 100-fs VECSELs (outlined green circles) and 184-fs MIXSEL (outlined orange square) results presented here are highlighted.

In particular, we demonstrate a high-power 96-fs SESAM-modelocked VECSELs with 100 mW average output power at a pulse repetition rate of 1.63 GHz [6]. The second VECSEL is similarly structured as the first one but is grown by molecular beam epitaxy instead of metalorganic vapor phase epitaxy and produces over 1 kW of pulse peak power with 101 fs pulses and an average output power of 150 mW at a pulse repetition rate of 1.12 GHz. The VECSELs are based on ten strain-compensated quantum wells (QWs) with an optimized distribution for a broad amplification bandwidth. The structural group delay dispersion (GDD) around the lasing wavelength is minimized, which is a key requirement for the record-short pulse durations. The VECSELs are modelocked by a QW SESAM in a V-shaped cavity together with a curved output coupler (OC).

In a MIXSEL, the QW saturable absorber is integrated into the gain structure of a VECSEL, which allows together with a curved OC for modelocking in a simple straight linear cavity. Further optimization of the structural GDD and the coating of the sub-300-fs MIXSEL by Mangold et al. [7] allowed to reduce the pulse duration to 184 fs with 115 mW of average output power at a pulse repetition rate of 4.33 GHz.

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