Compact, Diamond-Cooled and Stabilised Semiconductor Disk Lasers for Quantum Technology

Semiconductor disk lasers (SDLs) consist of an optically-pumped multi-quantum well active mirror in an external laser cavity. This format of semiconductor laser has a number of advantageous characteristics including power scaling with high beam quality, easy access to high intracavity power, and wavelength flexibility. Following the development of diamond-cooled AlGaInP based red SDLs at the IoP, we were able to implement intracavity frequency doubling to reach ultraviolet wavelengths [1]. SDLs are unique among semiconductor lasers in that they have very high finesse external cavities with high power and therefore their intrinsic linewidth is very narrow. They also have very low intensity and frequency noise compared to other lasers so long as the photon lifetime exceeds the carrier lifetime; however, this means that the external cavity must be a few cm long and therefore subject to environmental noise. Linewidths of a few kHz are usually achieved via active stabilisation to an external reference, most often a Fabry Perot (see e.g. [2]). The external reference adds bulk and complexity and is subject to drift. We have recently reported a 689nm SDL with linewidth of 5kHz for strontium atom cooling applications and demonstrated tuning with picometre precision via an intracavity diamond heatspreader acting as a variable etalon [3]. A broad range of compact ultra-narrow linewidth lasers, at novel wavelengths, are required for quantum technology; specifically metrology (based on optical clocks) where we aim to apply short wavelength (visible – ultraviolet) SDLs in collaboration with UK leaders in quantum science.

Project objective: In this project the student will develop narrow linewidth, diamond-cooled and stabilised SDL systems suitable for application in quantum technology. This work will take full advantage of the properties of diamond: enabling high power operation and providing thermal and mechanical stability. The research may include but is not limited to: design and optimisation of semiconductor gain structures, semiconductor processing, diamond processing, laser cavity engineering, optics and nonlinear optics, active stabilisation techniques and atom optics demonstrations with our collaborators. We will target novel results that will be published in the best journals in the field.

[1] Jennifer E. Hastie, Lynne G. Morton, Alan J. Kemp, Martin D. Dawson, Andrey B. Krysa, and John S. Roberts, “Tunable ultraviolet output from an intracavity frequency-doubled red vertical-external-cavity surface-emitting laser,” Applied Physics Letters 89, 061114 (2006).

[2] David Paboeuf, Peter J. Schlosser, and Jennifer E. Hastie, “Frequency stabilization of an ultraviolet semiconductor disk laser,” Optics Letters 38, p1736 (2013).

[3] David Paboeuf and Jennifer E. Hastie, “Tunable narrow linewidth AlGaInP semiconductor disk laser for Sr atom cooling applications,” Applied Optics 55, 4980 (2016).

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