Optical Parametric Oscillators: Technology and Applications

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Optical parametric oscillators (OPOs) continue to fulfil their promise as versatile sources of tunable coherent radiation for spectral regions inaccessible to lasers. More than 40 years after the demonstration of the first device, OPOs have now been established as viable and practical coherent light sources for a wide range of applications. The potential of OPOs derives from their exceptional wavelength versatility, which allows convenient access to substantial portions of the optical spectrum with a single device. At the same time, because of the instantaneous nature of nonlinear gain, OPOs offer unique temporal flexibility, which permits output generation in all temporal regimes from the continuous-wave (cw) to ultrafast femtosecond time-scales by appropriate choice of pump laser. The OPO also offers a compact all-solid-state design, is capable of delivering high output power and efficiency, and can provide high frequency stability and extensive fine tuning capability, and operates at or above room temperature without recourse to cryogenic cooling. These characteristics make OPOs highly competitive alternatives to conventional lasers and other technologies for the generation of widely tunable coherent radiation in difficult spectral and temporal domains.

Over the past decade, there has been remarkable progress in OPO device technology, driven by the emergence of new nonlinear materials and the availability of novel laser pump sources. The advent of birefringent crystals such as BBO, LBO, KTP, BIBO, as well as quasi-phase-matched (QPM) nonlinear materails including (MgO:)PPLN, PPKTP, (MgO:)sPPLT, and most recently OP-GaAs, have had an unprecedented impact on OPO technology and applications. Combined with the development of new solid-state, semiconductor and fiber laser pump sources, these have led to the practical realization of OPO devices with previously unattainable performance capabilities. In the current state of technology, OPOs can provide spectral access from ~230 nm in the UV to ~12 μm in the mid-IR, as well as the terahertz spectral range. They can also provide temporal output from the cw and long-pulse microsecond regime to nanosecond, picosecond, and ultrafast sub-20 fs time-scales.

This talk will provide an overview of the most important recent advances and current status of OPO device technology, from the cw to femtosecond time-scales and from the UV to mid-IR. The discussion will include perspectives on device architectures, nonlinear optical materials, and emerging applications of OPO sources. In the different device configurations and operating schemes, the impact of birefringent and QPM nonlinear crystals, deployment of novel resonator designs and pumping configurations, use of innovative fine tuning protocols, and exploitation of cascaded frequency mixing concepts on the attainment of the highest optical powers and efficiencies, most effective wavelength extension into the difficult UV and mid-IR spectral regions, highest spectral purity, and widest mode-hop-free tuning capability will be addressed, and practical deployment of cw OPOs in a applications such as spectroscopy, quantum information, optical frequency metrology, environmental gas detection and sensing, life sciences, imaging, and biomedicine will be highlighted.

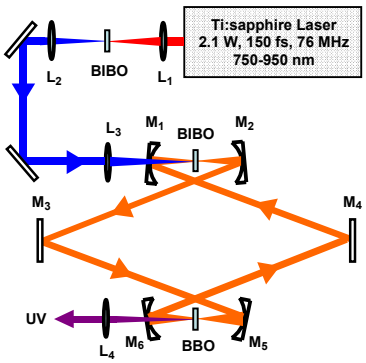

Fig. 1. UV generation with a femtosecond OPO [1].

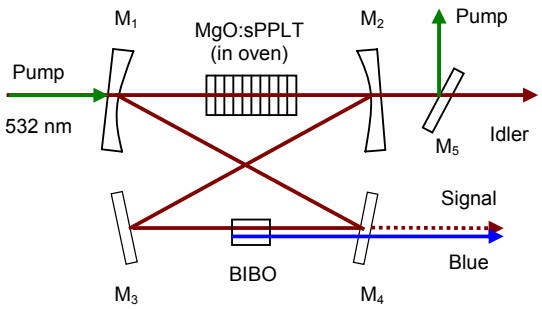

Fig. 2. Blue generation with a cw OPO [2].

References

[1] M. Ghotbi, A. Esteban-Martin, and M. Ebrahim-Zadeh, *Opt. Lett.* **33**, 345 (2008).
[2] G. K. Samanta and M. Ebrahim-Zadeh, *Opt. Lett.* **33** (2008).