COIL Radiation of High Brilliance

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High brilliance performance of chemical oxygen iodine lasers (COIL) requires resonator concepts that enable efficient power extraction from a low gain medium while the beam quality is close to the diffraction limit. Different resonator concepts are pre-evaluated by numerical methods and the promising candidates are adapted to a 10 kW-class COIL system. Theoretical predictions and experimental results are found to be in excellent agreement. The beam quality of different resonator architectures is evaluated by standards reported in literature.

The chemical oxygen iodine laser (COIL) is well known as a reliable source to produce laser output power up to the multi megawatt level. In addition, the high homogeneity of the gain medium provides the potential for near diffraction limited generation of laser radiation. Therefore, COIL is one of the most promising candidates for directed energy applications. This deployment demands excellent far field characteristics of the radiation. The resonator is no longer qualified by the extraction of high laser power, but by the generation of a beam quality that allows for a high power density far away from the laser source. The deployment also imposes additional requirements to the resonator concept like compactness and mechanical stability. While concerning real high power systems beam quality might not be an issue due to the applicability of well known unstable resonator designs. But much research has to be done at a reduced power level.

Efficient power extraction from COIL allows only low values for output coupling, due to the COIL inherent low gain medium. Because of the large COIL medium cross section, a stable resonator exhibits a high Fresnel number resulting in an high multi-mode operation with poor beam quality . Other resonator architectures have to be applied, depending on the class of output power.

For laboratory and demonstrator devices of the 10 kW class, hybrid resonators including off-axis modifications proved to be an excellent choice. They combine a stable with an unstable resonator. The composition of two independent resonator directions allows a cylindrical mirror design that is perfectly adaptable to the rectangular COIL geometry. The unstable part can be designed as negative branch or positive branch, depending on the curvatures of the resonator mirrors. Theoretical predictions and experimental results were found in excellent agreement, preferring the negative branch hybrid resonator (NBHR). Highest brilliance was achieved in a double-pass NBHR configuration. Unfortunately, the hybrid resonators suffer from two shortcomings: The beam quality in stable direction decreases with increasing mirror dimensions and an high alignment accuracy in stable direction is required. However, for 10kW class systems the hybrid resonator is convincing in performance.

For conventional unstable resonators with low gain, the total coupling loss has to be small. In consequence, the magnification has to be small. The result is a far field intensity distribution with a lot of structure and a very small peak power. Still at the 100 kW level the magnification is rather small. An off-axis modification of the classical resonator configuration (Modified Negative Branch Unstable Resonator, MNBUR) was introduced and tested at a 10 kW class device. It proved to be easily adaptable to COIL geometry while simultaneously reducing the far field intensity structures. Since the theoretical treatment is proved to describe actual resonators coupled to a 10 kW system, a specific MNBUR for high brilliance can be reliably designed for an adequate power in a 100 kW class COIL.

The beam quality of stable resonators with Gaussian type intensity distribution is well described by the beam propagation ratio M^2. Misleading results may occur when applying this criterion to unstable resonator configurations. The beam quality of different resonator architectures will be evaluated by standards reported in literature.

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