Mid-infrared high brightness direct-diode laser module

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The development of laser technology in the mid-infrared is leading to the emergence of industrial laser applications in this wavelength range, especially for materials which show enhanced absorption as compared to near-infrared wavelengths produced by prevalent laser sources. In this work, we present the development, construction and testing of a direct-diode, multi-watt, high brightness source at 2.1 µm wavelength by spatial beam combining of several broad-area single-emitters based on gallium antimonide (GaSb). The opto-mechanical design incorporates six individual emitters with fast and slow axis collimation each, combined in a staircase concept with matched optical path lengths. The laser enclosure measures 60 x 60 x 60 mm^3 including the beam-combining optics along with individual micro-Peltier temperature stabilisation, implemented by a custom 6-channel software PID loop based on a Raspberry Pi™ controller.

The optical assembly for each emitter consists of a fast axis collimator (FAC) made of anti-reflection coated molded KV-C89 glass with back focal length of 180 µm at 2.1 µm wavelength, chosen to minimise the bowtie effect based on a simple ray tracing model, as well as a slow axis collimator (SAC). To minimise the laser head footprint, the choice of SAC was limited to back focal lengths between 5 and 10 mm. A variety of off-the-shelf SACs were experimentally evaluated to determine the best obtainable beam quality in the slow axis. The optimal SAC was determined to be a f = 7.7 mm plano-convex cylindrical lens.

The matching of the optical path lengths before all the emitters are combined is shown to improve the combined beam quality, and the beam stacking tolerances are quantified with normalised parameters. The combined beam quality is shown to vary linearly with transverse spacing but is very sensitive to longitudinal misalignment. The theoretical and experimental optimisation of the beam quality enables a compact direct-diode laser with high brightness, which may prove to be a very attractive low-cost source for processing materials such as ITO and selected polymers.