Zhang, HuanLin, "Mid-Infrared Bragg Grating Photonic Devices: Tunable Lasers and Optical Pre-Amplifiers"

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Mid-infrared (mid-IR) photonics such as lasers, optical amplifiers, and detectors have important applications in spectroscopic sensing, biomedical diagnostics, environmental monitoring, and defense. Spectroscopic sensing requires lasers with broad wavelength tenability and narrow linewidth. Remote sensing often involves weak signals that can benefit from optical preamplifiers for high-sensitivity receiver. The objective of this dissertation is to develop wavelength-tunable mid-IR lasers and optical pre-amplifiers using Bragg gratings. Bragg grating is a key photonic technology for wavelength control, optical mode coupling, and beam shaping. Specifically in this work, advanced surface-emitting Bragg grating is applied to develop novel mid-IR tunable lasers and optical preamplifiers.

Bragg-grating device development includes design, fabrication, and experimentation. For grating fabrication, a holographic setup using an Ar+-laser and based on Lloyds mirror configuration has been built for patterning. Several grating transfer techniques have been investigated.

Two tunable laser approaches have been developed. The first approach employs an external in-band AlGaAs/GaAs Bragg-grating waveguide that is coupled with a quantum cascade laser. This configuration allows wavelength control via the Bragg grating that is separate from the gain segment and impervious to the latter's wide operation temperature variation. Stable wavelength operation at ~5.13 µm with ~ 20-nm tuning range was achieved. The second approach uses an integrated off-band surface-emitting Bragg grating, which has negligible reflection inside the cavity and allows free-space coupling to an external mirror to form a linear cavity. Wavelength control was achieved with a combination of coarse and broad wavelength tuning (140 nm) with the external mirror and continuous, fine wavelength tuning (1.85 nm) via current-induced phase shift in the Bragg grating. An essential and novel feature is the separate electrical controls of the two segments, which allows wavelength fine-tuning without power variation and vice versa.

The off-band surface-emitting Bragg grating was also used to develop mid-IR optical pre-amplifiers that are capable of integrated ASE-filtering and wavelength-division-multiplexing. A device has been developed on a 4.7-μm quantum cascade laser wafer with a net optical gain of >13 dB, and an ASE-filtered noise-power spectral density of -99 dBm/Hz1/2. In summary, mid-IR photonics based on Bragg gratings are highly promising for many applications.