Widely tunable mid-IR monolithic coherent source

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InGaAsP lattice-matched to InP is widely used for optoelectronic components such as lasers, detectors and modulators. For the design of these devices, knowledge of refractive index is critical. While it has been well described up to 1.55 µm[1-4], only one publication offers its measurement at longer wavelengths[5], with limited precision. We have performed an accurate characterization of the refractive index up to 3.14 µm, lengthening the wavelength range and offering a significant increase in precision. This data is exploited to design a tunable source in the mid-IR range, through spontaneous downconversion (SPDC) of a laser beam at 1.55 µm.

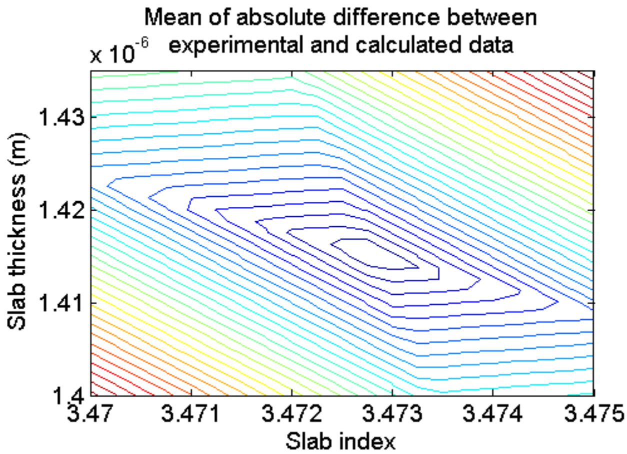

Figure 1. Determination of refractive index and thickness of an InGaAsP slab on InP at a wavelength of 1.55 µm. This figure shows the mean difference between calculated and measured effective indices. Area width gives an estimation of the error.

In the index measurement, we point a laser onto an InGaAsP slab waveguide covered by an integrated Bragg grating and mounted on a rotating stage. Light couples in at discrete values corresponding to the effective indices of guided modes. Since these effective indices are a function of both refractive index and thickness of the slab, it is necessary to measure more than one mode in order to lift the ambiguity. Fig. 1 shows the average difference between the measured and expected effective indices for a given slab thickness and index. Taking all uncertainties into account, we achieve a precision of 10^{-3} on the material index.

Index data is used to design a monolithic widely tunable source around 3 µm, by internal SPDC in a laser diode. The device consists of an InGaAsP/InP quantum-dash laser emitting at 1.55 µm, in which the laser field acts as a pump for intracavity SPDC towards a signal and idler around 3.11 µm. To compensate for the material dispersion, the index profile is tailored to ensure that the laser will emit on a higher-order mode of the waveguide. We show that the ridge width provides a useful parameter to reach phase matching despite the fabrication tolerances associated to epitaxy. The effective-index mismatch that must be set to 0 to achieve an efficient conversion is equal to

$$\Delta n = nTE_2(\lambda_{pump}) - [nTE_0(\lambda_{signal}) + nTM_0(\lambda_{idler})]/2 \quad (1)$$

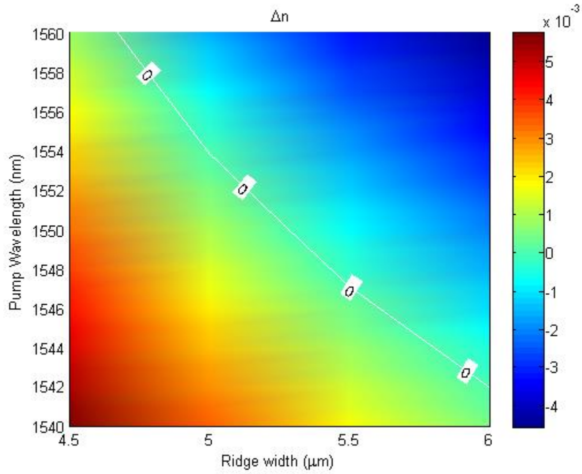

Figure 2. Effective-index mismatch as a function of ridge width and pump wavelength

As is apparent in Fig. 2, a shift of the wavelength satisfying phase matching at degeneracy can be readily compensated by a choice of a different ridge width, at the end of fabrication. Additionally, the signal and idler wavelengths can be widely modified outside of degeneracy by modifying the temperature during operation. The expected efficiency of this device is 240 % W^{-1} cm^{-2}.

References:

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