Single-mode DBR Laser Diodes for gas detection with Grating Structures fabricated by NIL

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Within the NaPa project a single mode DBR laser diode was realized to demonstrate the potentials of nano imprint lithography (NIL) in optoelectronic device fabrication. NIL has been used for this kind of devices to replace electron beam lithography for the DBR grating structure. The results obtained show the feasibility to implement the NIL technology with all its potentials (e.g. in mass production and low cost devices) in the fabrication process of semiconductor laser devices.

Starting with commercially available laser structures a ridge waveguide has been processed on the wafer surface using optical lithography and ICP dry etching processes. At the end of the laser ridge a metal grating has been fabricated by using NIL and lift-off technology. Silicon stamps with dry etched grating structures have been used to transfer the gratings first into a polymer film. The residual polymer layer was then removed by an O2 ashing step followed by metalization and lift-off processes. In figure 1 a metal grating section of a DBR laser is shown. The figure shows a scanning electron microscope picture of a first order metal grating with a grating period in the order of 270nm. The width of the metal lines fabricated by NIL is around 85nm. The optimization of the silicon stamps and the parameters for the NIL process resulted in a very good homogeneity and reproducibility of the grating structures over the whole grating area as it can been seen in figure 1.

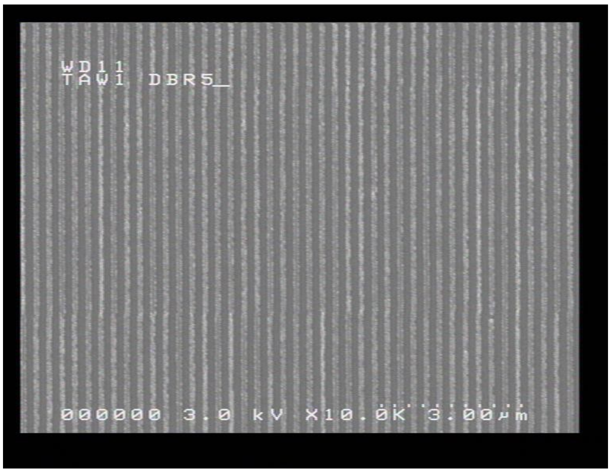

Figure 1: SEM picture of a metal grating structure fabricated by NIL. Grating period 270nm

The imprinted DBR grating has been fabricated at one end of the laser ridge and acts as a frequency selective mirror. This results in single mode laser emission whereas the emitting wavelength can be easily tuned by changing the period of the DBR grating.

In figure 2 an emission spectrum of a DBR laser diode in continuous wave (cw) operation is shown. The laser diode emits only at one single laser mode with a wavelength of 1685.2nm. For all other modes the side mode suppression ratio (SMSR) is almost 40dB or even more.

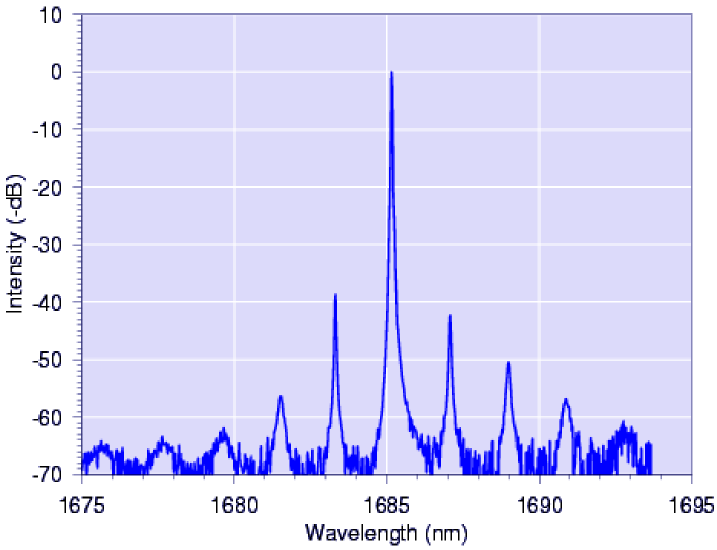

Figure 2: Emission spectrum of a DBR laser diode with NIL grating section.

In the first place the emitting wavelength of the laser diode is defined by the grating period of the DBR section. Furthermore the wavelength can be fine tuned by changing the temperature of the laser or the operation current. As an example in figure 3 emission spectra for different laser operation currents are shown.

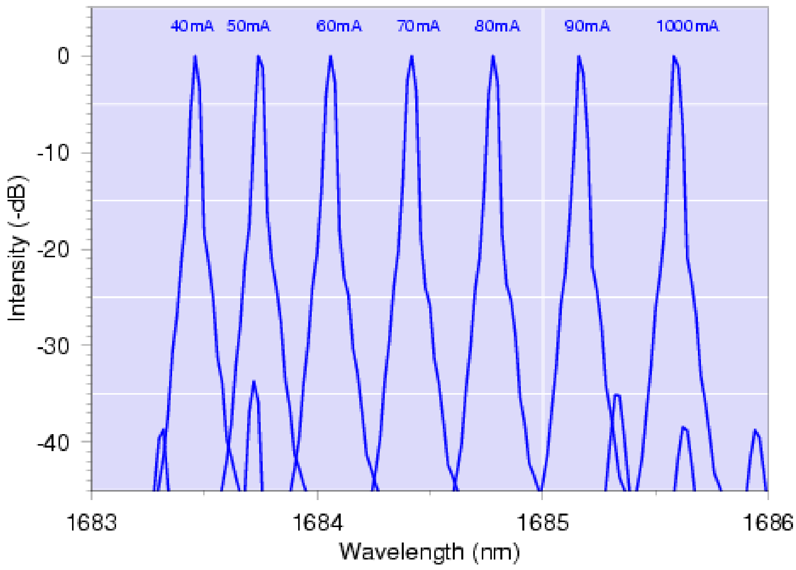

Figure 3: Current tuning of the emission wavelength of a laser diode.

The drive current of the laser diode is varied from 40mA up to 100mA. For all currents the emission stays single mode with a SMSR of more than 35dB. The maximum of the laser emission shifts from 1683.4nm at 40mA to 1685.6nm at 100mA. This allows a continuous tuning of the laser emission by current over an tuning range of more than 2 nm.

In conclusion the work within this task has demonstrated the big potential of NIL as a cost efficiency and high throughput technology for optoelectronic device fabrication. DBR single mode laser diodes with emission lines around 1684nm with grating structures processed by NIL has been demonstrated. The devices show single mode emission with a SMSR ratio of 35dB and more. A tuning range by current of more than 2nm is possible as a result of a high coupling between the NIL grating structure and the stimulated emission within the laser cavity.