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Publication date:
2013

Citation (APA):
Smistrup, K., Nørregaard, J., Mironov, A., Bro, T. H., Bilenberg, B., Nielsen, T., ... Zhang, Y. (2013). DWDM laser arrays fabricated using thermal nanoimprint lithography on Indium Phosphide substrates. Poster session presented at The 57th international conference on Electron, Ion, and Photon Beam Technology and Nanofabrication, Nashville, Denmark.

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Dense Wavelength Division Multiplexing (DWDM) lasers play a major role in today's long-haul broadband communication. Typical distributed feedback (DFB) laser cavities consist of long half-pitch gratings in InGaAsP on InP substrates with pitches around 240 nm. Lasers are made reliably single mode by including a lambda quarter shift at the center of the grating. The need for phase shifts and multiple wavelengths eliminates some lithography methods such as holography. Typically, these lasers are produced by e-beam lithography (EBL). We present a production method based on thermal nanoimprint lithography (T-NIL), which is potentially less costly and faster than EBL.

NIL Technology and NeoPhotonics designed a stamp with the structures shown in Figure 1. The stamp was fabricated using EBL and dry etching. The line width on the stamp was 40 nm to accommodate for line broadening in subsequent processing steps and the structures were placed on mesas on the stamp.

T-NIL of these structures presents three major challenges: 1) The imprinted structures must be aligned to the crystallographic direction of the InP substrate within 0.1°; 2) InP is a fragile material that will break under high pressure; 3) InP and Si have different thermal expansion coefficients, so temperatures must be kept low in order to maintain the designed pitches in the final devices.

The imprinting was performed using NILT's CNI tool. The imprint resist used was mr-I7020E spun to a thickness of 160 nm. Imprint pressure, temperature and time were 3 bar, 80°C, and 20 minutes, respectively. The release temperature was 55°C. The residual layer was removed by oxygen plasma. A representative AFM of the imprinted and etched grating structure is shown in Figure 2.

The low imprint pressure ensures that the fragile InP substrate is not damaged during the imprint process and the narrow temperature window for imprint and separation (80°C and 55°C) ensures minimal issues with thermal mismatch between the InP substrate and the Si stamp.

The imprinted InP wafers were processed in NeoPhotonics standard process line to create working lasers. The fabricated lasers were cleaved and measured. Laser arrays exhibited >40mW optical power in all 12 channels. Figure 3 shows the overlaid spectra of a 12-channel array laser chip with uniform (~3nm) wavelength spacing and good sidemode suppression.

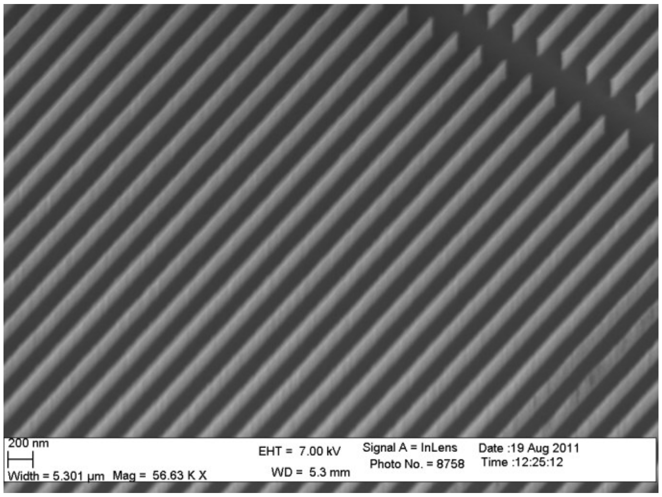

Figure 1: Tilted SEM image showing the stamp structures. The protrusions are 40 nm wide, 10 µm long and 200 nm high with pitches varying around 240 nm.

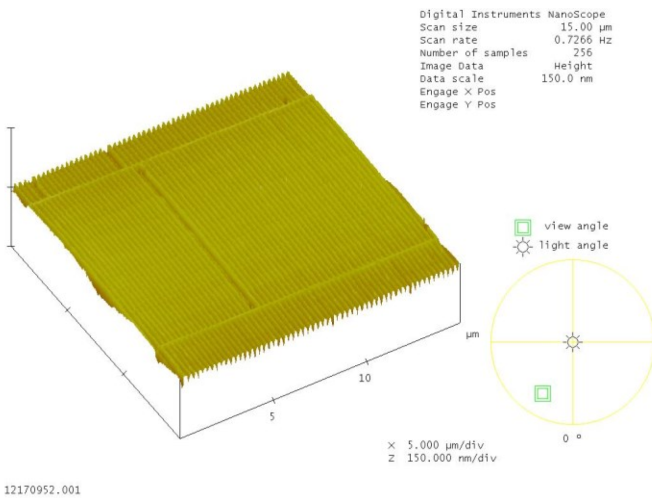

Figure 2: AFM image of the imprinted and etched InGaAsP grating layer. The image shows part of a laser channel including the phase shift.

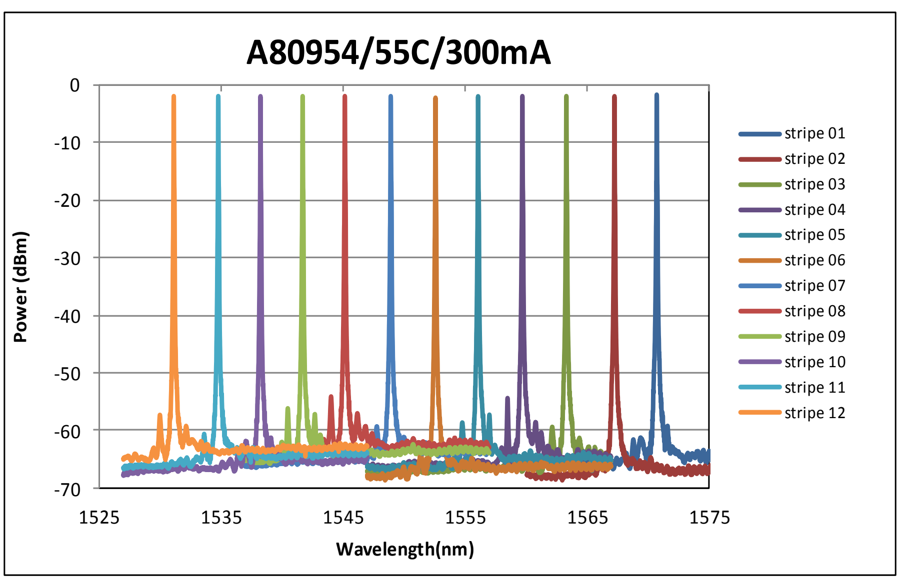

Figure 3: Overlaid spectra of a 12-channel array laser chip. Each laser is measured separately at 55°C and 300mA.