Micro assembly of separate devices by transfer printing

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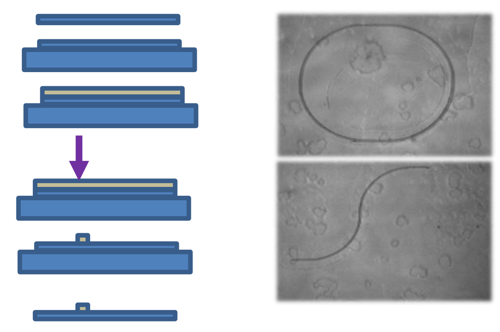
Motivation

- PICs: Application range from optical communication technologies [1] to optical sensing [2].
- Solutions to efficient hybrid device integration rely on high precision assembly of multiple independently fabricated structures [3].
- We report the micro assembly of photonic passive devices by a pick-and-place technique.
- Multiple substrates are bonded containing pre-fabricated waveguide structures integrated by a pick-and-place technique.
- These include the fabrication and assembly of vertically coupled polymer micro-ring resonators.

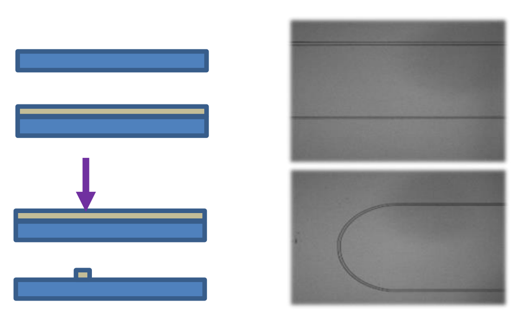
Methods

Device Fabrication: *All devices were fabricated by a custom built direct-write laser lithography tool and standard photolithography process*

Flexible glass substrate (printed)



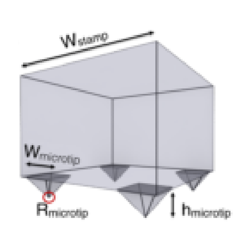
Target glass substrate



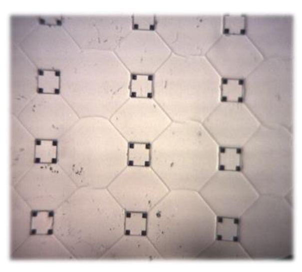
µTransfer Printing Technique

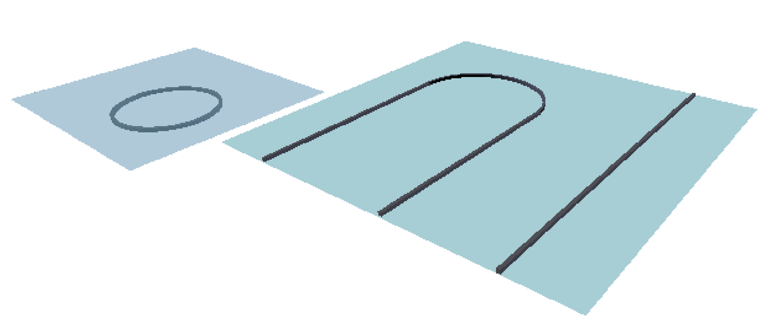
Pick-and-place performed on converted dip-pen nanolithography patterning tool (NanoInk Inc. NLP 2000)

Elastomeric stamp array (shown right) inserted into system to adhesively print structures

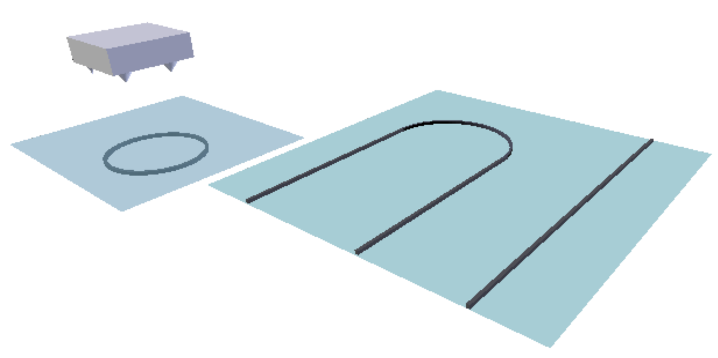


[4]

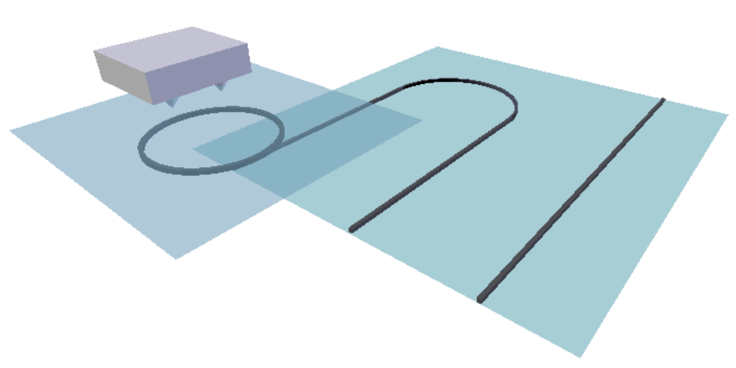




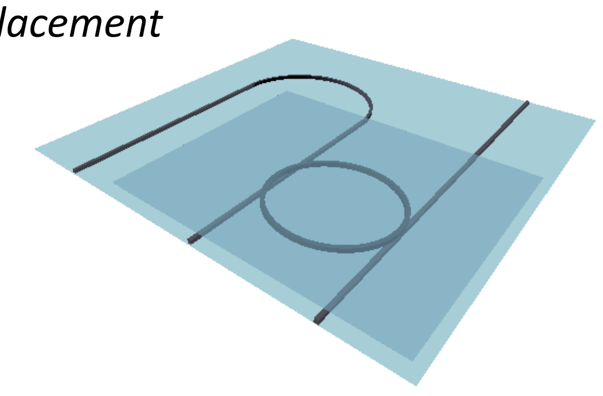
1. Flip the flexible substrate such that devices are facing down. This is to allow contact between structures on each device.



2. Align transfer stamp to substrate. Focus imaging system through PDMS elastomeric stamp to allow precise placement



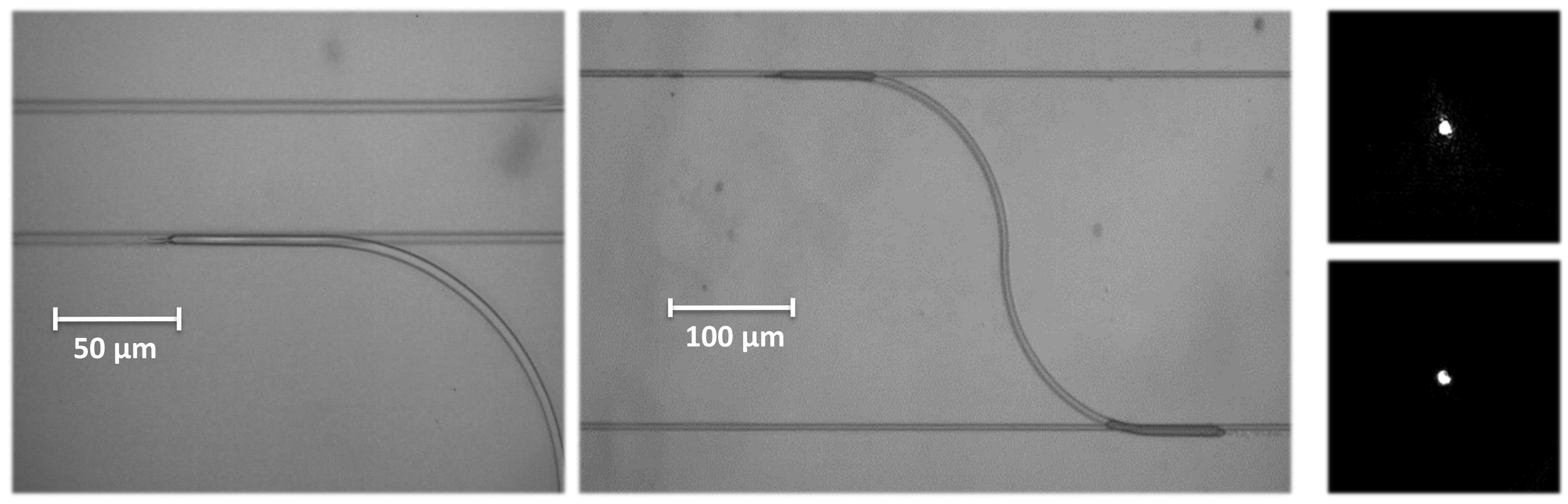
3. Pick up flexible substrate with elastomeric stamp. Align to structures on target substrate before final step



4. Place flexible substrate and devices in contact with target substrate. Utilise capillary bonding of structures by use of solvent layer

Results

Waveguide-to-waveguide coupling

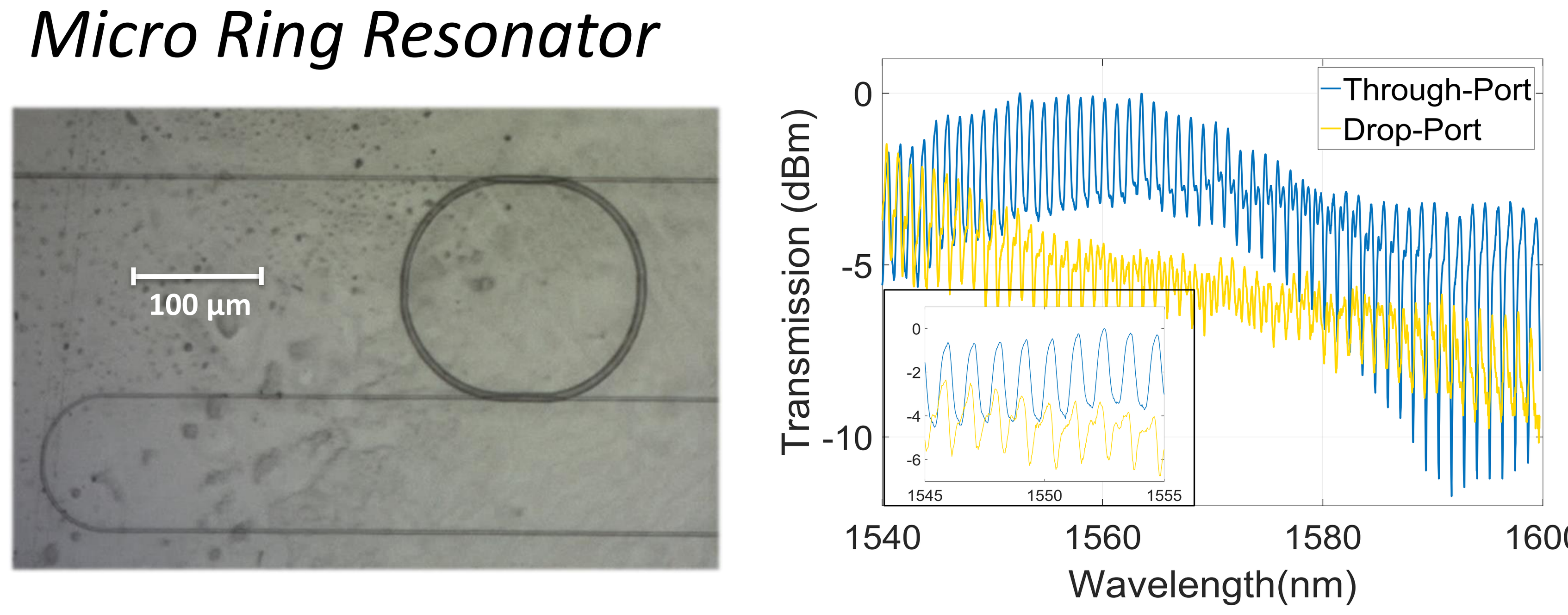


(a) (b) (c)

Figure 1 (a) Magnified image of coupling region (coupling length 80µm). Image focus on upper substrate
(b) Image of full integrated structure. Bend waveguide on flexible substrate, two straight waveguides on target substrate
(c) Output mode profiles of through waveguide (upper) and coupled waveguide (lower)

- Coupling percentage of 6.6% calculated from transmission measurements

Micro Ring Resonator



(a) (b)

Figure 2 (a) Image of micro-racetrack ring resonator (coupling length 60µm).
(b) Normalized transmission spectra of ring resonator. Input injection power of 1.1mW. Through-Port and Drop-Port resonances achieved from assembled resonator structure as a function of wavelength.

- Multi-mode resonances measured from output transmission
- Coupling coefficients: fundamental mode K=60%, secondary mode K=90%
- Resonator quality factor: fundamental mode Q=10,000, secondary mode Q=73,000

Conclusions

- Micro assembly of independently fabricated polymer waveguide structures to produce micro-racetrack resonator devices
- The vertical coupling of light between bonded substrates for the control of light over multiple waveguide structures
- Resonator quality factor as high as 10k achieved from assembled ring resonator

[1] A.F. Benner, M. Ignatowski, J.A. Kash, D.M. Kuchta, and M.B. Ritter, "Exploitation of optical interconnects in future server architectures ",*IBM Journal of Research and Development*, 49, 755-775 , 2005.
[2] C.Y. Chao, W Fung, and L.J. Guo ," Polymer microring resonators for biochemical sensing applications", *IEEE Journal on Selected Topics in Quantum Electronics*, 12, 134-142 , 2006.
*[3] X. Sheng, C. Robert, S. Wang et al., "*Transfer printing of fully formed thin-film microscale GaAs lasers on silicon with a thermally conductive interface material ", *Laser and Photonics Reviews*, 9, L17-L22 , 2015
[4] J. Wu, S. Kim, W. Chen, A. Carlson, K.-C. Hwang, Y. Huang, and J. A. Rogers, "Mechanics of reversible adhesion," Soft Matter, vol. 7, pp. 8657–8662, 2011.