# FlexWave—Silicon Flexure Systems with Inkjet-printed Waveguides

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*Optical waveguide structures have been tested on silicon flexures. Prior art focused on inkjet-printed waveguide structures on rigid substrates. This work deals with the challenges associated with printing waveguides on flexures. Preliminary results show successful realization of small waveguides on flexures and no significant mechanical issues with a large number of cycles. By the end of the project the optical performance over cycles will be validated and if proven successful, a gripper structure with integrated sensors will be realized. This gripper illustrates a whole range of new integrated sensor opportunities and opto-mechanical structures on precision flexure systems for applications in watch-making, micro-assembly etc.*

There is a major global trend towards additive manufacturing like 3D printing as it allows unprecedented customization of functional pieces. Inkjet printing is a mature, contactless process within additive manufacturing, which offers a comparably high throughput while still being suitable for a variety of materials and substrates (especially curved or fragile parts). Previously CSEM has shown its capability of using inkjet printing for creating optical waveguides with losses of 0.61 ± 0.26 dB/cm [1].

The integration of optical sensors into (micro-) mechanical systems has also received a lot of attention recently, as they can achieve high resolutions, are insensitive to surrounding electrical fields and can operate under strong spatial confinement. CSEM silicon flexure systems have been used for the creation of MEMS, micro-components for mechanical watches, micro-assembly, miniature robots and beam steering [2]. Within these contexts, integrating photonics and optics for the purpose of sensing adds a significant value. An example of a system that can benefit of integrated sensors is the gripper shown in Figure 1.

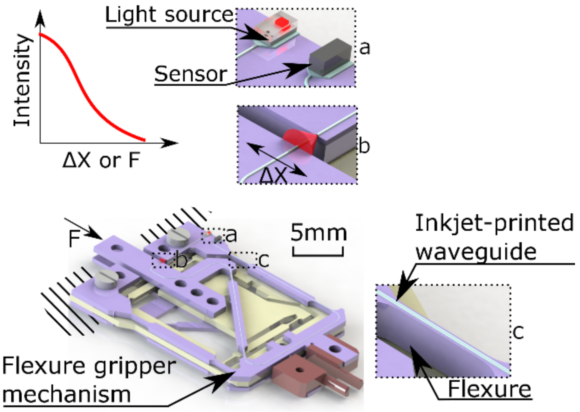


*Figure 1: Combining flexure mechanisms, e.g., a flexure gripper mechanism, together with inkjet-printed wave guides for intensity based sensing of displacement (ΔX) or force (ΔF).*

Investigating whether waveguide structures operate properly on silicon flexure systems addresses two challenges: the limited surface area for depositing the waveguide and the required performance over a large number of cycles.

The first challenge comes from the fact that the flexure systems are very small: Typically, flexures are around 50 microns wide and narrow rigid bodies require radii of curvature of 300 microns for connecting the waveguides on the individual flexures.

In the context of this project, a process has been developed for printing waveguides with widths in the order of 50 µm and alignment precisions in the µm range. The process was optimized to yield waveguides with a width corresponding to the size of a single droplet (≈40 µm) with sufficiently small radii of curvature (300 µm, potentially lower values could be reached).

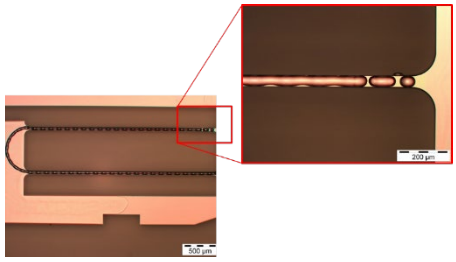

*Figure 2: Waveguide printed on top of narrow 50 micron Si beams.*

The second challenge is the optical and mechanical performance over large numbers of cycles. The number of cycles required is application dependent but the more the better. A typical range of interest is 1e3 to 1e7 cycles. A custom fatigue setup was created to evaluate optical and mechanical fatigue.

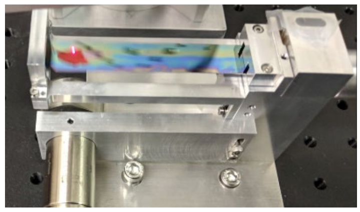

*Figure 3: A custom designed opto-mechanical fatigue measurement setup with a silicon flexure moved for 1e7 cycles.*

The preliminary results on mechanical fatigue look promising, as no significant mechanical damages have been observed during first tests with up to 1e7 cycles. The optical fatigue is currently being evaluated. If successful, the optical structures will be printed on top of the gripper illustrated in Figure 1 and assembled as a demonstrator for the technology.

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[1] P. M. Theiler, F. Lütolf, R. Ferrini, "Non-contact printing of optical waveguides using capillary bridges", Opt. Express 26, 11934-11939 (2018).

[2] J. Kruis, F. Barrot, L. Giriens, D. Bayat, R. Fournier, S. Henein, S. Jeanneret, “Design and fabrication of a novel centimeter scale three dimensional silicon tip, tilt and piston mirror mechanism,” in EUSPEN 2013, Berlin, 2013.