# Microfluidic Multimode Interference Device

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*Abstract*—**A multimode interference device has been fabricated using a novel ultra-precision micromachining technique. The micromachining technique defines the interfaces of the device by cutting microfluidic channels into a silica-on-silicon substrate. Changing the refractive index of fluid within these microfluidic channels is shown to alter the optical characteristics of the device.**

***Keywords- MMI; microfluidics; micromaching; silica-on-silicon***

## I. INTRODUCTION

Multimode interference (MMI) devices have many applications in photonic integrated circuits such as optical power splitting, switching and demultiplexing [1]. They typically exhibit a simple structure, with low loss, a compact size, polarization insensitivity, low cross talk and a good fabrication tolerance.

The use of etched trenches to define MMI interfaces has previously been suggested as a design improvement for platforms with associated low index contrast, such as silica-on-silicon [2]. Trenches can act to improve optical confinement, thus enhancing image quality and device performance. Trenches can also have the advantages of reduced heat dissipation, thermal cross talk [3], bend loss [4] and stress birefringence [5]. In this work the concept of using trenches is extended to form microfluidic channels.

Microfluidics allows the manipulation of small volumes, with precise dynamic control [6]. Interfaced with integrated optics the possibilities of device design can enhance microanalysis, including optical trapping and separation, monolithic integration of lasers and optical detection, all of which has been recently reviewed [7].

The presented work highlights a novel way of fabricating MMI components using a computer controlled ultra-precision micromachining process, illustrated in Figure 1. The sawing process is similar to that used in the microelectronics industry and is capable of fabricating ridges, trenches and V-grooves. Trenches of 10 μm can be defined with typical side wall roughness Ra value of 9 nm. The technique gives the freedom from expense and time investment associated with photolithography and etching, whilst allowing rapid prototyping, design flexibility and the potential of three-dimension structure fabrication.

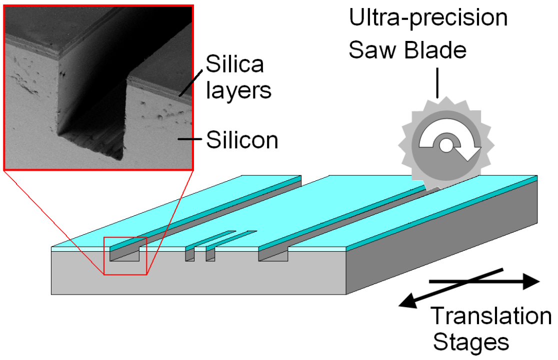

Figure 1. A conceptual illustration depicting multimode inteference device fabrication through ultra-precision micromachining

If the side walls of the MMI device are defined by microfluidic channels the device's optical characteristics can be changed by simply replacing the fluid in the microfluidic channel with another. Changing the refractive index of a fluid will alter the Goos-Hänchen shift associated with the device and thus alter its effective width [8]. This phenomenon is illustrated in Figure 2 (a) and (b), which show simulations of the novel MMI construction in silica-on-silicon, with an index of 1.3 and 1.44 in the microfluidic channels respectively. Over identical lengths the image shifts from a 1x3 fold image to a 1x4 fold image.

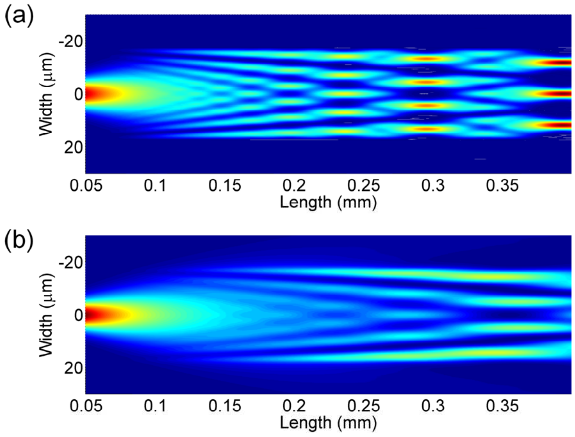

Figure 2. A beam propagation simulation of a multimode inteference device with microfluidic sidewalls, depicting a fluid of refractive index (a) 1.3 and (b) 1.44 in the microfluidic channels

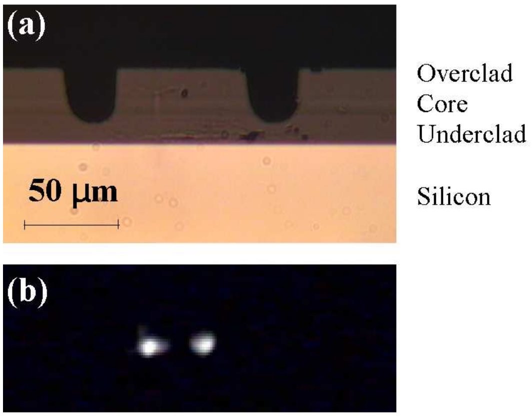

Figure 3. An endface of the fabricated device as viewed by (a) a light-microscope and (b) an IR-CCD camera with 1550 nm launch

## II. FABRICATION

The reported device has been micromachined from a silica-on-silicon composite, fabricated using flame hydrolysis deposition. The composite consists of three silica layers, an underclad, a core layer and an overclad, as shown in Figure 3. To ensure lateral single mode operation the 5 µm thick central core layer was doped with germanium such to achieve a higher index than the surrounding cladding layers. For this first proof-of-principle device two trenches were micromachined into the silica using a 30 µm width saw blade, pictured in Figure 3 (a). Light was launched into the device via a single mode direct UV written channel [9]. The resulting MMI device had a width of 72 µm a length of 2.46 mm and had an antisymmetric launch offset of 7 µm. To assist characterization of the fabricated device the end face was polished.

## III. RESULTS

Launching 1550 nm TE light into the fabricated MMI device resulted in an antisymmetric image as the input launch was antisymmetric. The image observed from an IR-CCD camera is shown in Figure 3 (b). The resulting mode profile was characterized by scanning an optical fiber mounted upon a translation stage along the output facet of the device and monitoring the coupled power. The input power was set to 6.3 mW and the positional error of the translation stage was approximated to be 0.5 µm. Figure 4 compares the empirical data collected with respect to simulated data for such a device. The simulation is computed using a fast Fourier transform beam propagation method. The end face power is convoluted with a Gaussian profile comparable to that of the fiber optic used to collect the empirical data.

The empirical data shows significant correspondence to the simulated data. For both an air clad and an index of 1.44 in the micromachined trenches.

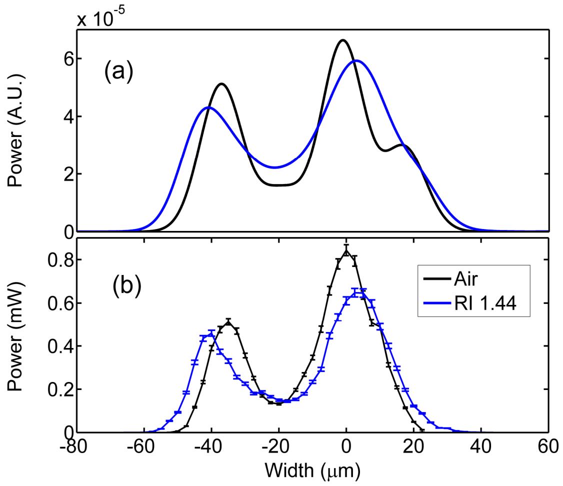

Figure 4. Characterisation of the output face of the fabricated MMI device interpreted through (a) simulation and (b) empirical measurements

## IV. CONCLUSIONS

A novel ultra-precision micromachining technique for fabricating multimode interference devices has been reported. Through exploiting the fabricated trenches as microfluidic channels the optical characteristics of the device can be manipulated.

The work shall report upon micromachined MMI devices and the considerations required for optimizing optical surface quality, including insertion loss measurements and minimum achievable feature size. MMI architectures which utilize microfluidic properties shall also be explored, including optical trapping and separation, monolithic integration of lasers and optical detection.

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