A Fiber-to-Chip Grating Coupler for the Ge-on-Si Platform at 5µm wavelength

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Abstract: We present efficient TM fiber-to-chip grating couplers that couple light between a single mode InF fiber and Germanium-on-Silicon (Ge-on-Si) waveguides in the 5 µm wavelength range. In recent years, Ge-on-Si has emerged as a platform of interest for sensing applications beyond 4 µm [1, 2]. Ge has low losses for light in the 4-12 µm range, which makes it suitable for the realization of mid-infrared (midIR) photonic integrated circuit gas and liquid sensors.

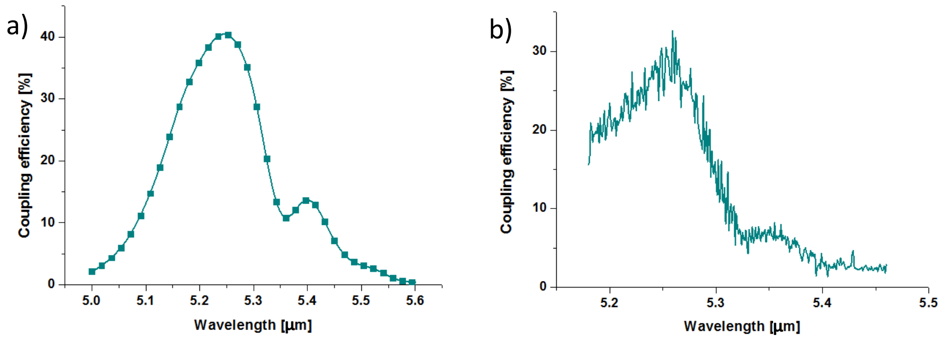

Fig 1. Simulated fiber-to-chip coupling efficiency as a function of wavelength (a) and the measured couping efficiency of the grating (b)

Grating coupler design: Since for a number of midIR applications QCL sources are used, emitting TM polarized light, we have opted to design fiber-chip interfaces for TM polarization. The couplers are designed in a 2 µm thick Ge waveguide layer on a silicon substrate. The TM grating coupler for the Ge-on-Si platform has a period of 1.42 µm, a 80% duty cycle (defined as the ratio of the width of the unetched tooth and the grating period) and an etch depth of 0.9 µm. The waveguides are partially etched with the same etch depth. The simulated coupling efficiency is 40% with a 3dB bandwidth of 180 nm at a central wavelength around 5.22 µm (Fig. 1a), for a fiber angle of $\theta = 5°$. The simulated reflectivity of the grating is below 1%, as calculated by 2D FDTD.

Fabrication and measurement: The grating and the waveguide are both defined with e-beam lithography and etched in one step using a chromium mask and a CF_4/H_2 plasma. Due to the fabrication imperfections the duty cycle of the fabricated device is 0.82, while the period and the etch depth is close to the targeted value. The best overlap of the fiber mode and the fundamental TM grating mode was achieved for a 27.5 µm wide grating. The top view and cross-section of the characterized device is shown in Fig. 2. The measurement system is schematically shown in Fig. 3b. Light from the free-space external cavity QCL operating in CW is coupled to the InF fiber by a ZnS lens. Between the laser and the lens we have a chopper and a Babinet-Soleil polarization control element.

The chopper turns the CW light into 50% duty cycle pulses and hence allows us to detect light on an InSb detector in combination with a pre-amplifier and lock-in system. The polarization control element is used to maximize transmission through the device at the central wavelength. Since the polarization at the fiber output facet is wavelength dependent we have measured the TE/TM ratio as a function of wavelength at the fiber facet by placing a wire grid polarizer and a thermal detector directly under the input fiber and comparing this power with measurement on the thermal detector without the grid polarizer (Fig. 3a). This ratio we took into account when measuring the total laser power in CW mode on the InSb detector (dashed line in Fig. 3b). The loss caused by the difference in length of the fiber when measuring the chip (full line in Fig. 3b) and when measuring the QCL power directly (dashed line in Fig. 3b) is not negligible in the wavelength range of interest and is evaluated from [3].

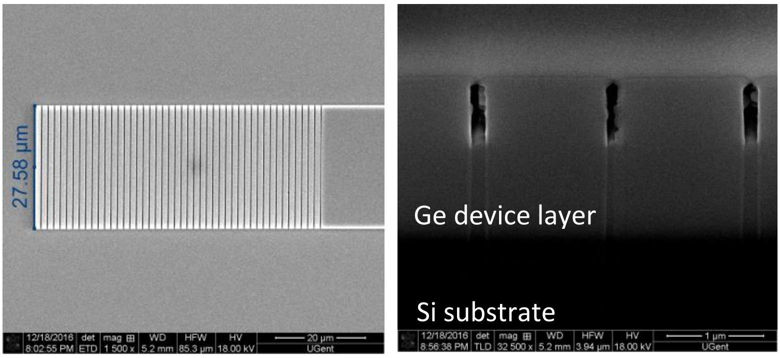

Fig. 2. Top view (left) and cross-section (right) of the Ge-on-Si grating coupler

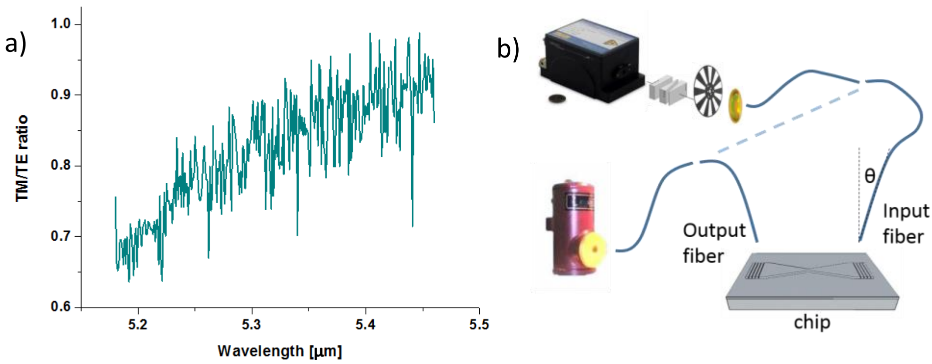

Fig 3. The TM to TE ratio vs. wavelength (a) and the measurement setup (b)

The experimentally characterized grating coupler shows -5dB (30%) coupling efficiency and a 3 dB bandwidth of 150 nm (Fig. 1b). The variations in the coupling efficiency are attributed to variations in the laser output power and measurement system and not to grating reflections.

References

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