Inducing second-order susceptibility in amorphous silicon nitride waveguides

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Optical waveguides based on stoichiometric silicon nitride (Si_3N_4) grown via low-pressure chemical vapor deposition (LPCVD) provide a reliable photonics platform characterized by low loss and a spectrally broad transparency ranging from the visible to the mid-infrared. Engineering the waveguide dispersion is of special interest since it allows phase-matching of third-order nonlinear optical processes such as four-wave mixing, supercontinuum and frequency comb generation.

Second-order nonlinear processes such as second harmonic generation (SHG) have been observed already in other types of silicon nitride that cannot offer such low loss, such as grown via RF-sputtering. As in such amorphous materials there should be no bulk nonlinear second-order response, $\chi^{(2)}$, fabrication imperfections such as strained micro-crystalline silicon or at the free nitrogen dangling bonds were suggested as the origin [1]. Field enhancement in Si_3N_4 ring resonators and Bragg gratings have been used to increase the efficiency for SHG, with a maximum conversion efficiency of 0.14% [2].

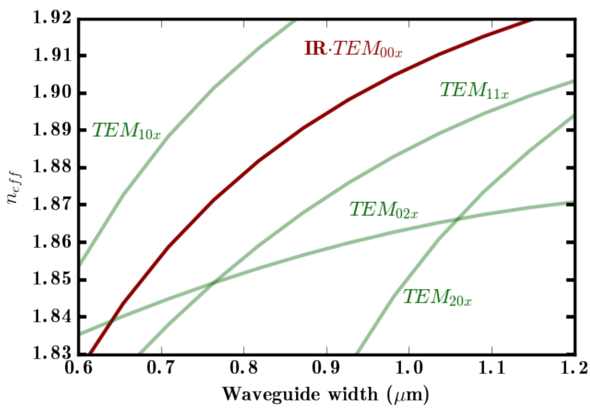

Fig.1. Effective refractive index of the different guided modes for IR and its SH in waveguides of 1 µm by width.

Here, we present for the time SHG in stoichiometric Si_3N_4 waveguides grown with LPCVD. Fig. 1 shows the modal dispersion vs. waveguide width which implies that phase-matching should only occur at a certain waveguide width. However, SHG was

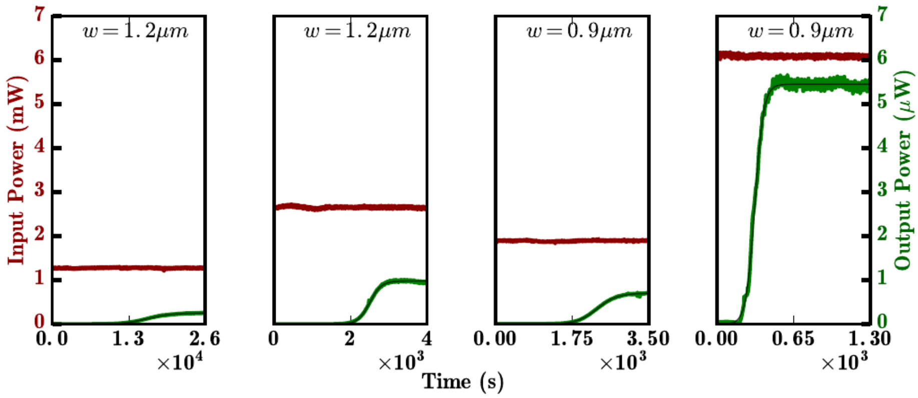

Fig. 2. Generation of photoinduced $\chi^{(2)}$ in four waveguide widths, w, and lengths 60, 74, 74, and 22 mm respectively.

observed with various different waveguide widths. Secondly, the output was seen to grow vs. time as shown in Fig. 2, when injecting the pump pulses from a mode-locked laser (6 ps pulses at 1064 nm with a 20 MHz repetition rate) with a constant average pump power.. These results show that the pump radiation induces a temporally growing nonlinear coefficient in the waveguides with a spatially periodic pattern that provides quasi-phase matching. The maximum conversion efficiency achieved so far is 0.5%, corresponding to 50 μW of 532 nm radiation with 10 mW of IR input radiation.

References

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