Development of neutral atom traps based on a microfabricated waveguide

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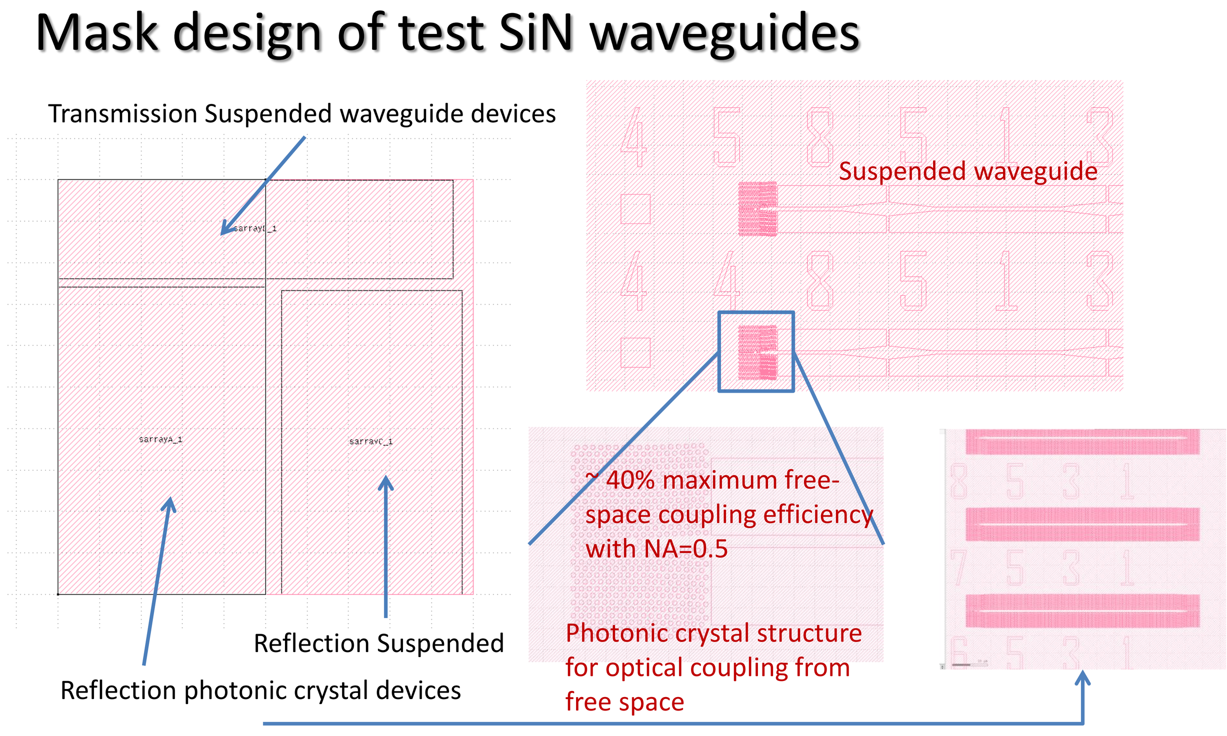
Abstract:

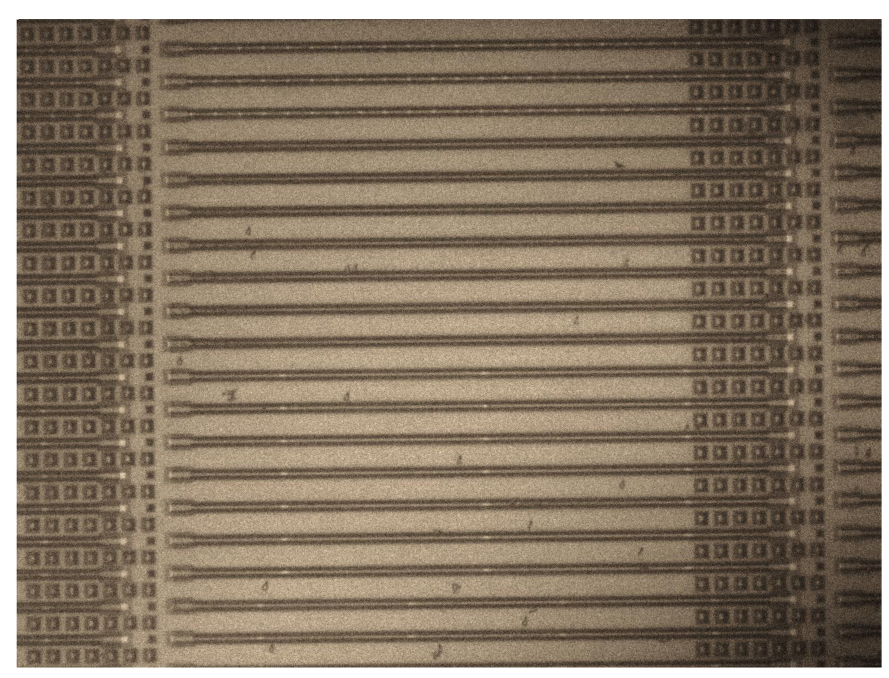
Implementation of trapping neutral atoms in the evanescent fields generated by a nano-structure, such as a nanofiber or a microfabricated nano-waveguide, will naturally enable strong atom-photon interactions, which serve the key mechanisms for different type of quantum controls. At Sandia National Labs, we are aiming to develop a platform based on this concept to eventually trap cesium atoms with a microfabricated waveguide. Although, neutral atom traps using optical nanofiber has been demonstrated, there are several key issues that need to be resolved to realize trapping atoms with microfabricated structure. The subjects include the material for making the waveguide, optical power handling capability, surface adsorption of alkali-metal atoms, surface roughness of the nano-structure, cold-atom source for loading the atoms into the evanescent-field traps, etc. On this poster, we report our latest progress.

Microfabricated suspended waveguides and detection of thermal Cs atom signals:

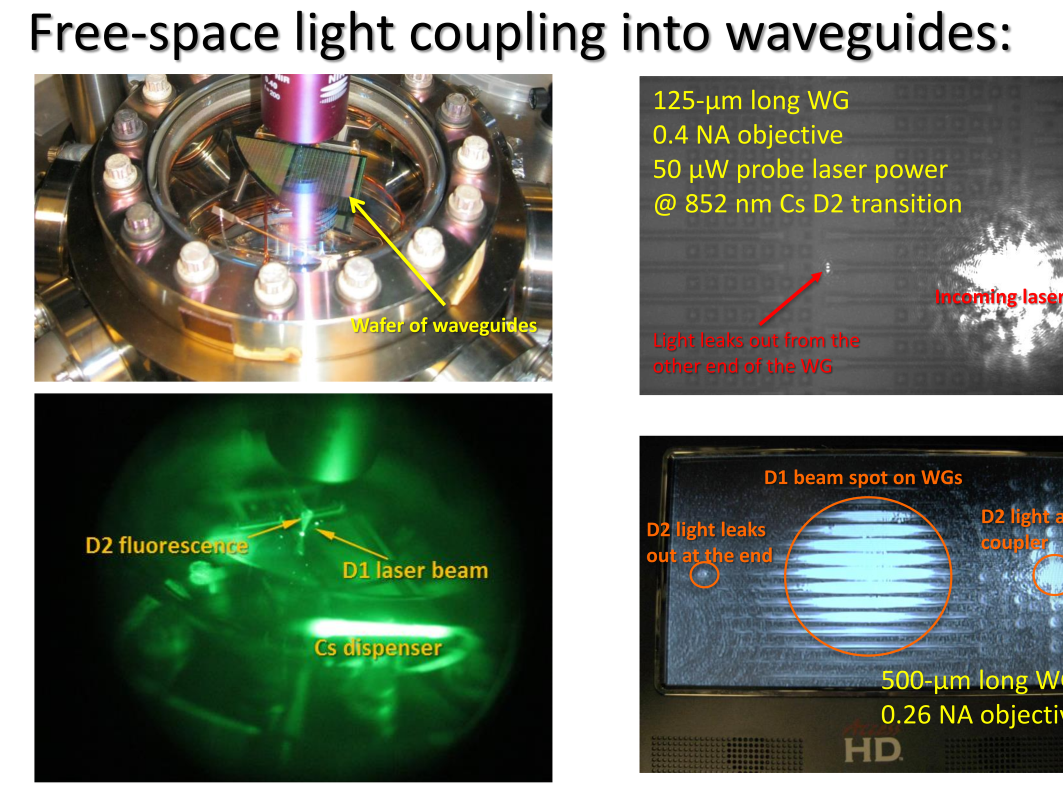
Mask design of test SiN waveguides



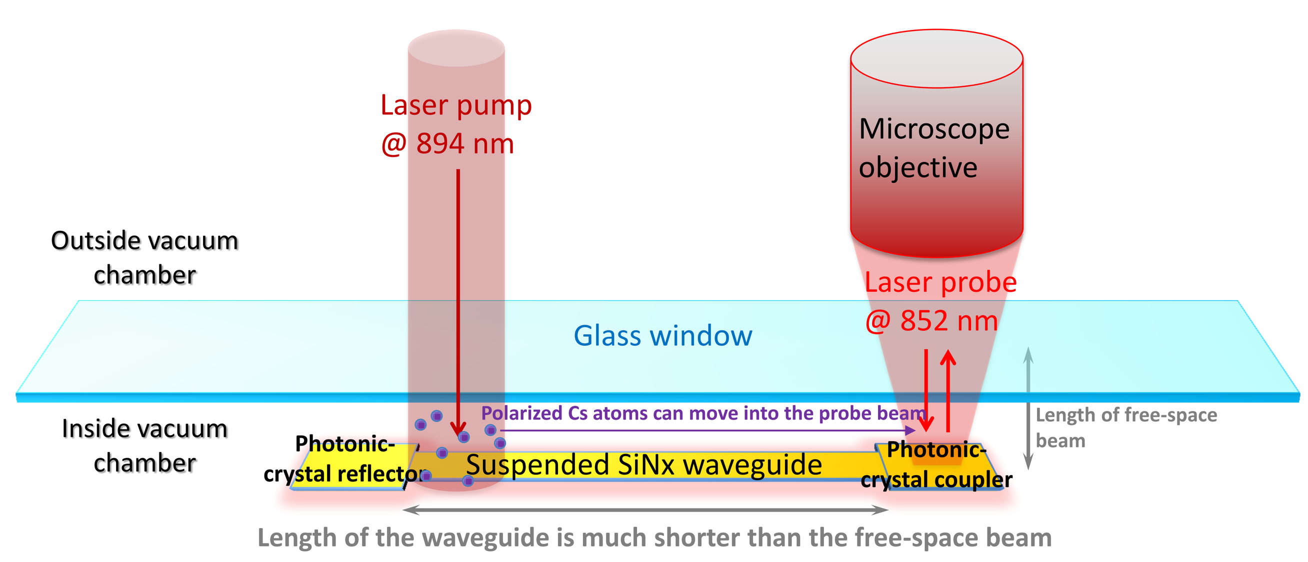
Picture of fabricated waveguides:



Free-space light coupling into waveguides:

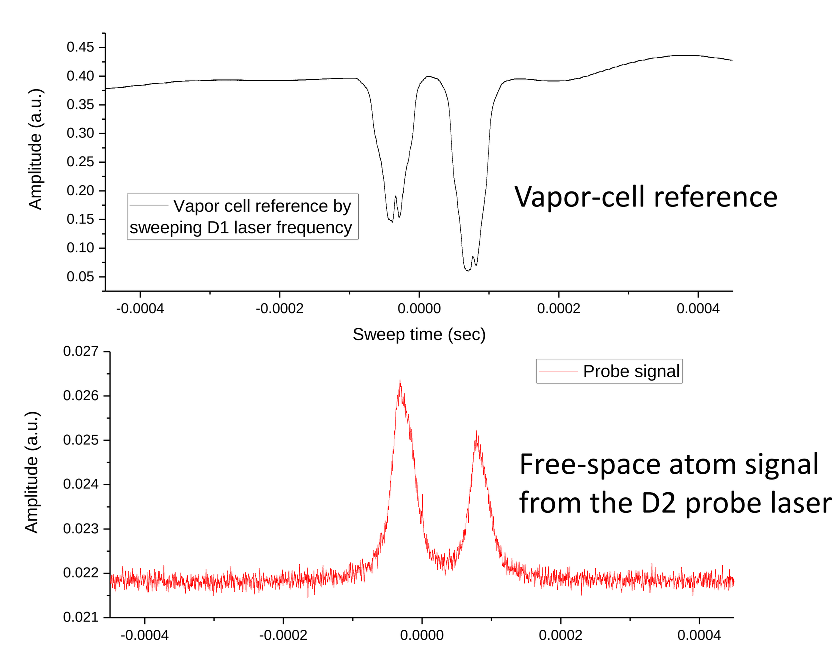


Experimental setup for atom signal detection:

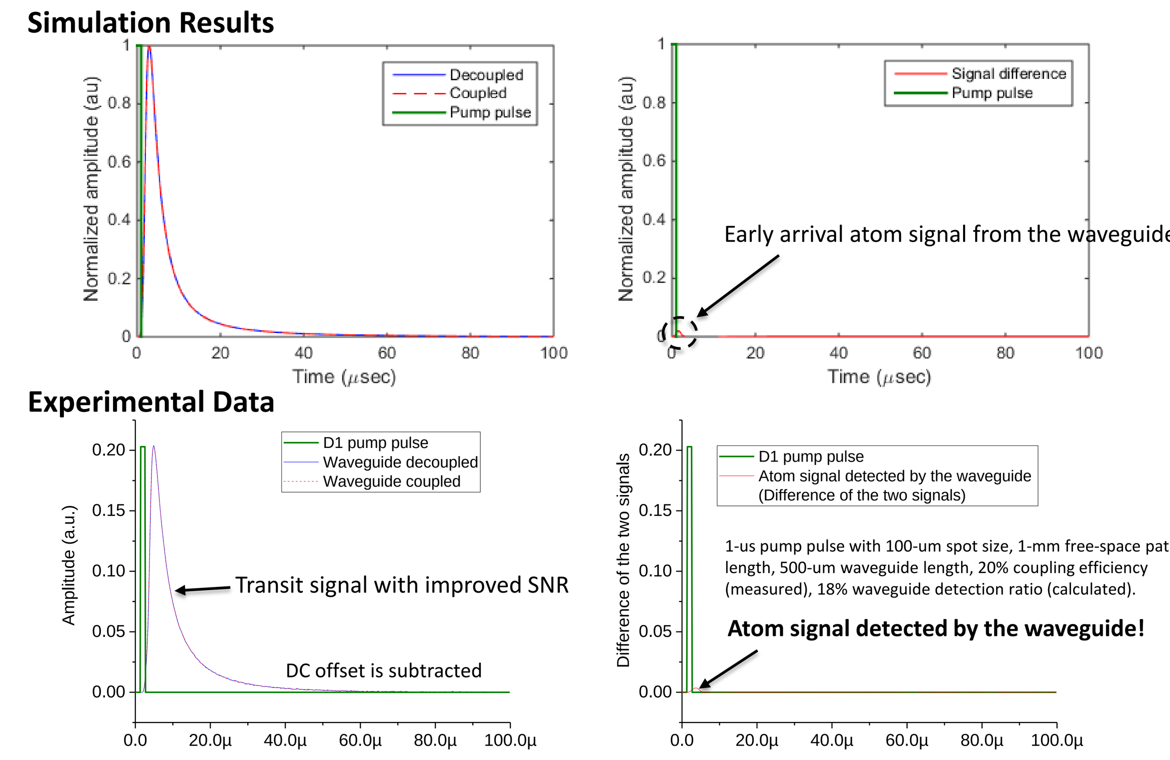


The probe beam is tuned on a Cs resonance. The pump laser is used to polarize Cs atoms by doing hyperfine optical pumping. The polarized atoms do not attenuate the probe light. Ideally, the probe laser is guided by the waveguide and its evanescent field can be used to detect the polarized atoms. **However, both the evanescent fields from the waveguide and the probe beam propagating through free space can see polarized atoms.**

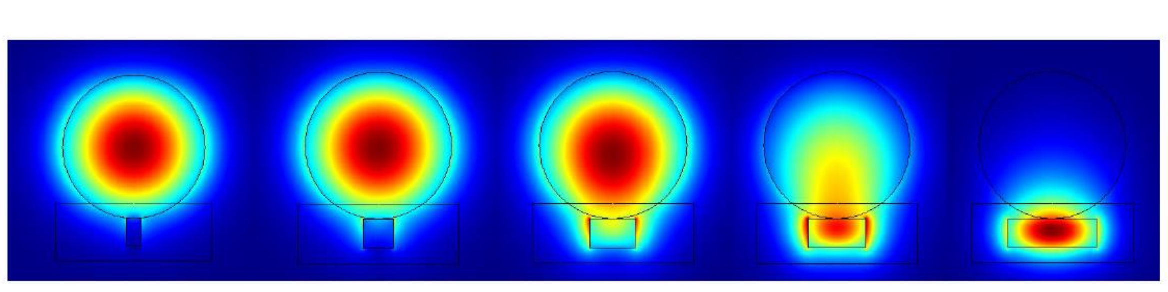
Free-space atom signal:



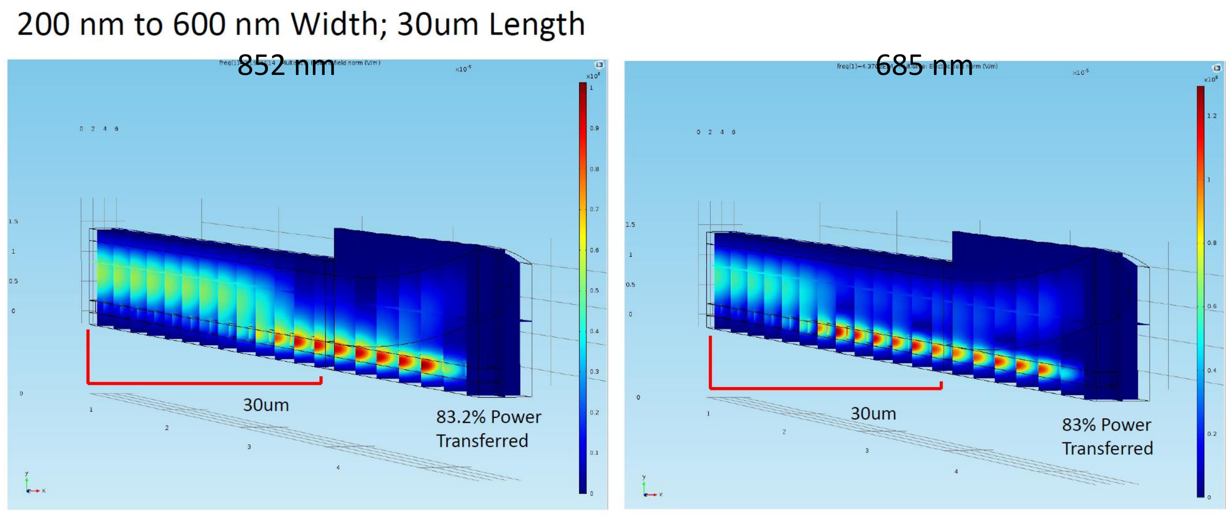
Detection of atom signal from waveguides:



Broadband optical coupling to waveguides via adiabatic transfer coupling:



200 nm to 600 nm Width; 30um Length



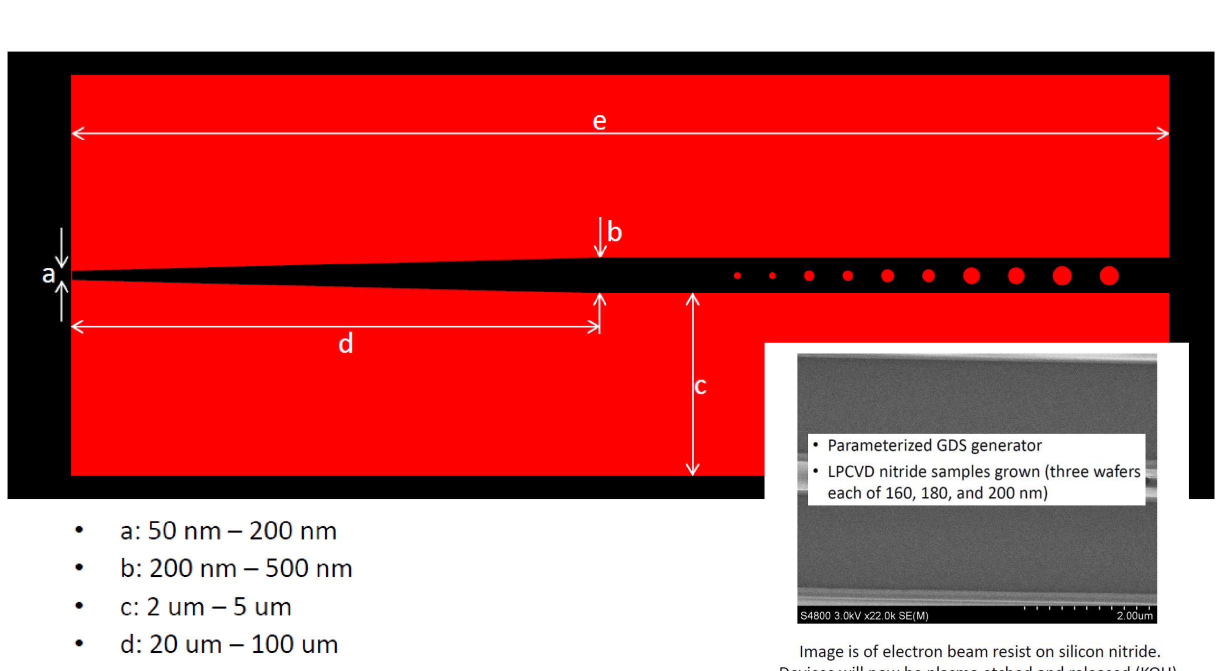
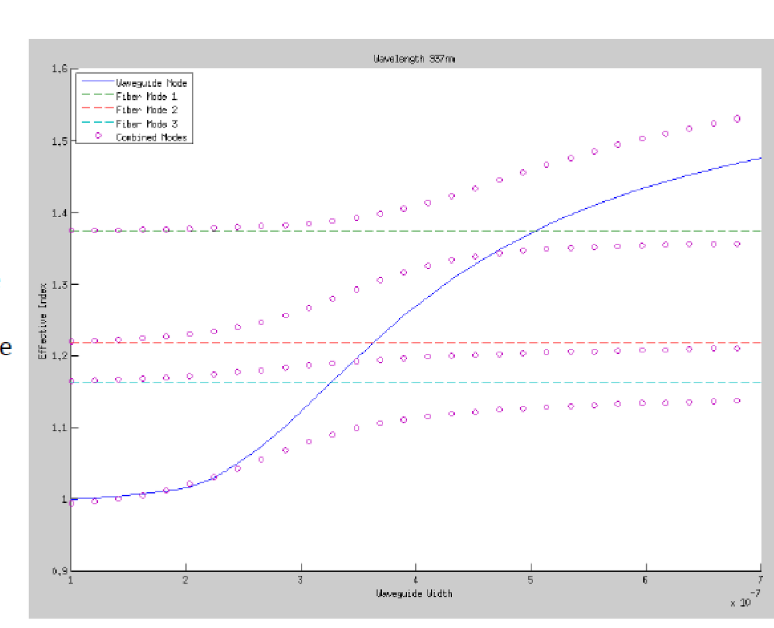
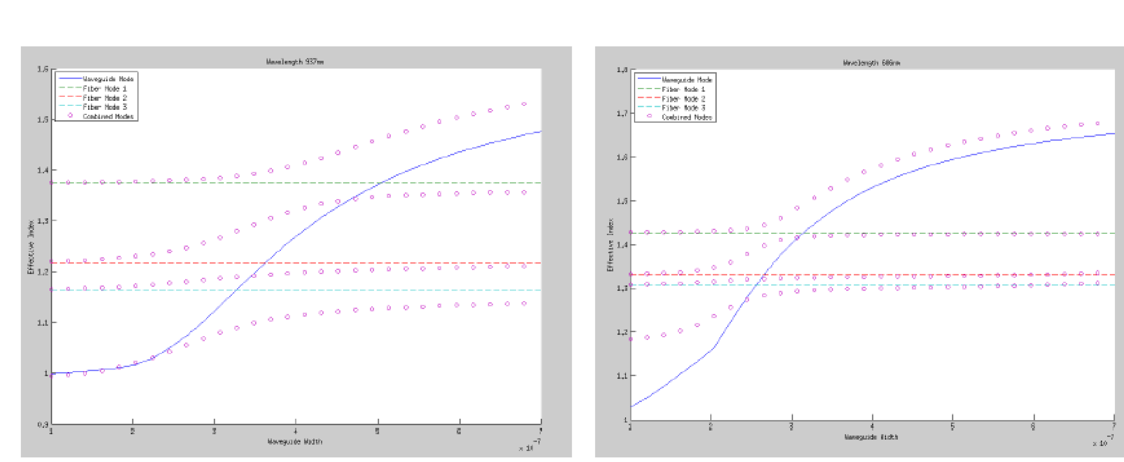


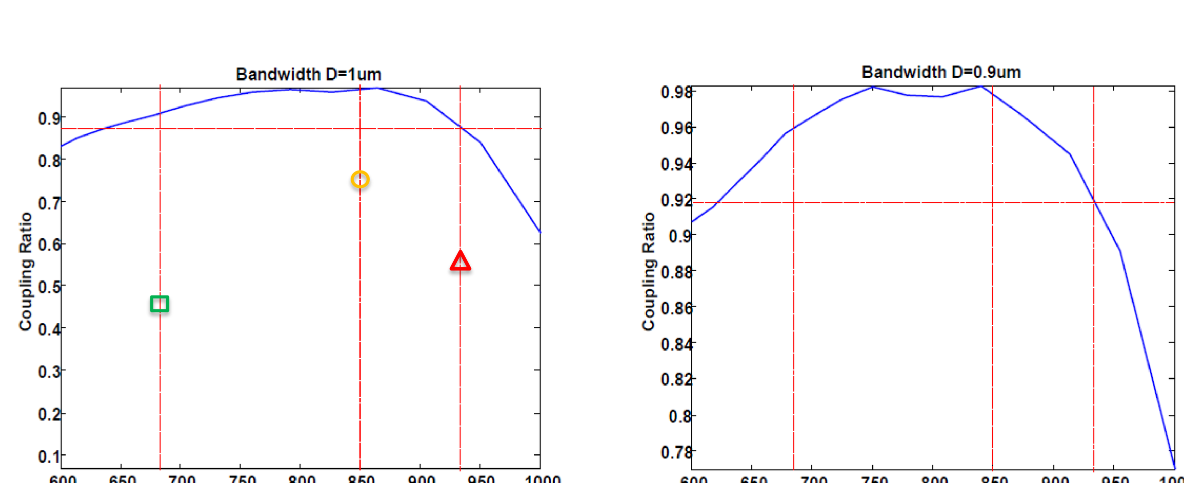
Image is of electron beam resist on silicon nitride. Devices will now be plasma etched and released (KOH).

- a: 50 nm – 200 nm
- b: 200 nm – 500 nm
- c: 2 um – 5 um
- d: 20 um – 100 um
- e: d+20 – 40 um
- Holes are illustrative at this point. They may end up being corrugations in the sides of the waveguide, but the aspect ratio compared to the waveguide width will be similar to what is shown here regardless of the topology.

- Geometry
  - 1 um diameter fiber
  - 200 nm thick Si_3N_4 waveguide
- When waveguide is thin, most of the energy resides in the fiber
- As waveguide is made thicker, the wg mode becomes resonant with the fiber mode
- In the coupled system, there is an anti-crossing of the modes which re-orders the eigenmodes of the coupled system
- Adiabatic tuning of the waveguide thus allows a state transfer to occur for the nth mode



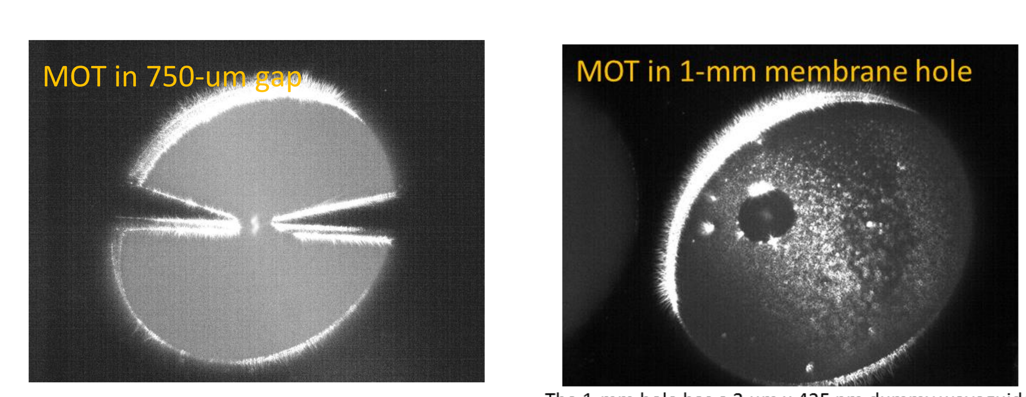




□ ○ △ are the lower-bound experimental data points for 685 nm, 852 nm, and 937 nm from the preliminary experimental characterization.

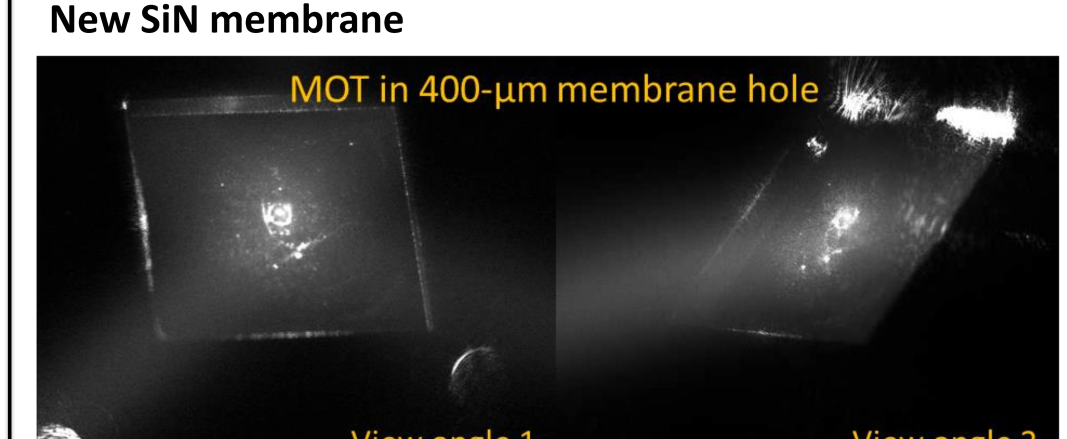
MOT clouds inside fabricated structures:

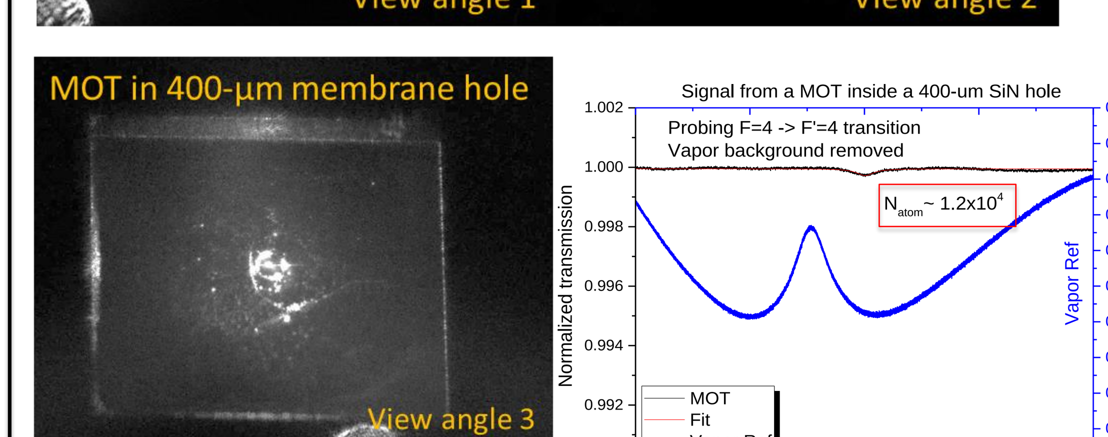
Si needle structure **Old SiN membrane**



The 1-mm hole has a 3 μm x 425 nm dummy waveguide

New SiN membrane





The 400-μm hole has a 3 μm x 125 nm dummy waveguide

We have demonstrated more than 10000 cold atoms inside a 400-um SiN membrane hole.

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