SAND2017-8585C

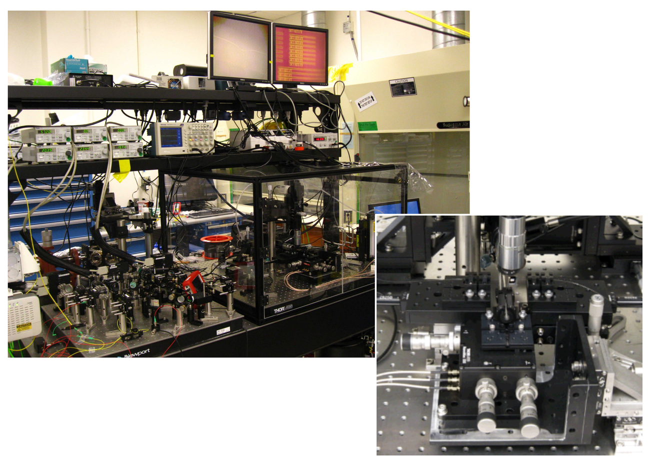
Characterizations of SiN and AlN microfabricated waveguides for evanescent-field atom-trap applications

Jongmin Lee, Matt Eichenfield, Erica Douglas, John Mudrick, Grant Biedermann, Yuan-Yu Jau

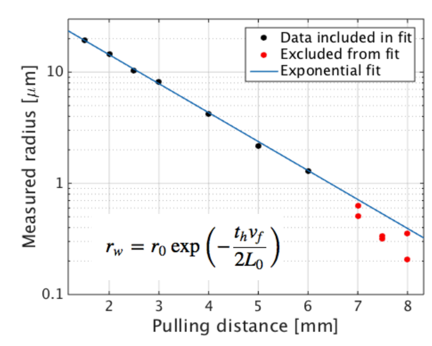
Abstract:

Trapping neutral atoms in the evanescent fields generated by microfabricated nano-waveguides (WG) will provide a new platform for neutral atom quantum controls via strong atom-photon interactions. At Sandia National Labs, we are aiming at developing the related technology that can enable the efficient optical coupling to the waveguide at multiple wavelengths, fabrication nano-waveguides to handle required optical power, more robust waveguide structure, and the new fabrication geometry to facilitate the cold-atom experiments. We will report our latest results on the related subjects.

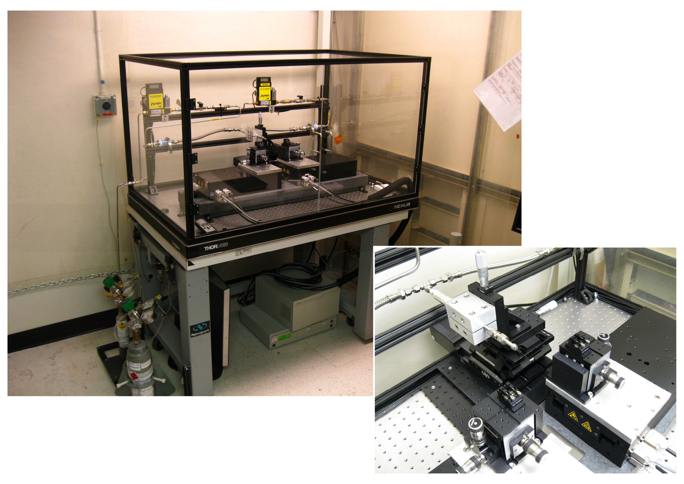
WG Probe Station with a dimple fiber



- Current fiber puller with H2 torch
- 1-µm diameter fiber pulling
- Dimple fiber molding for evanescent-field coupling
- PZT controlled sample stage for WG coupling
- Using this setup as a sample probing station in clean room



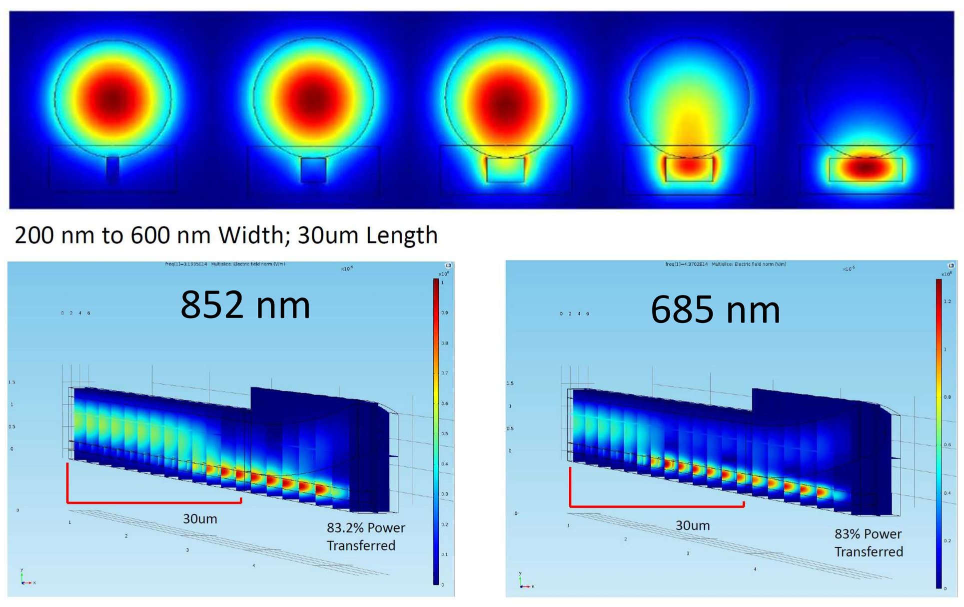
Nanofiber development

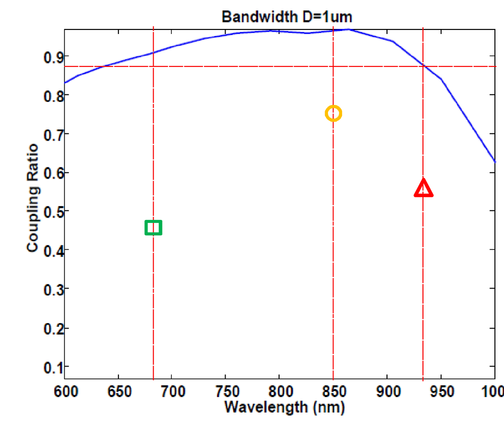


- Able to produce sub-µm diameter fibers reliably with fiber-pulling algorithm
- Two precise linear motor stages on a common granite base in clean room
- Known solution (VCQ/OIST/JQI) is Hydrogen/Oxygen torch to reduce air flow and control effective flame width.
- Custom Hydro-Oxygen torch tip

Evanescent-field coupling to WG

- 1.1-µm diameter tapered optical fiber
- A dimple fiber molding for WG coupling
- 200nm thick AlN and SiNx waveguides
- Photonic crystal (PhC) reflectors for 685nm, 852nm, 938nm lights (Cs atom trapping and probing)





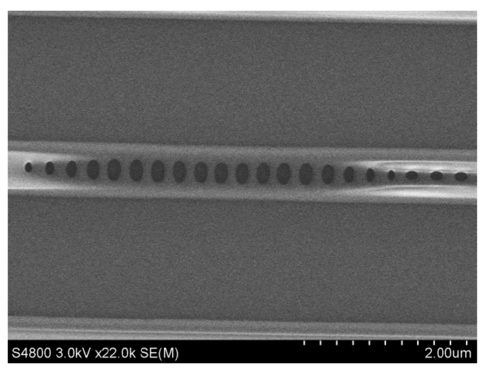
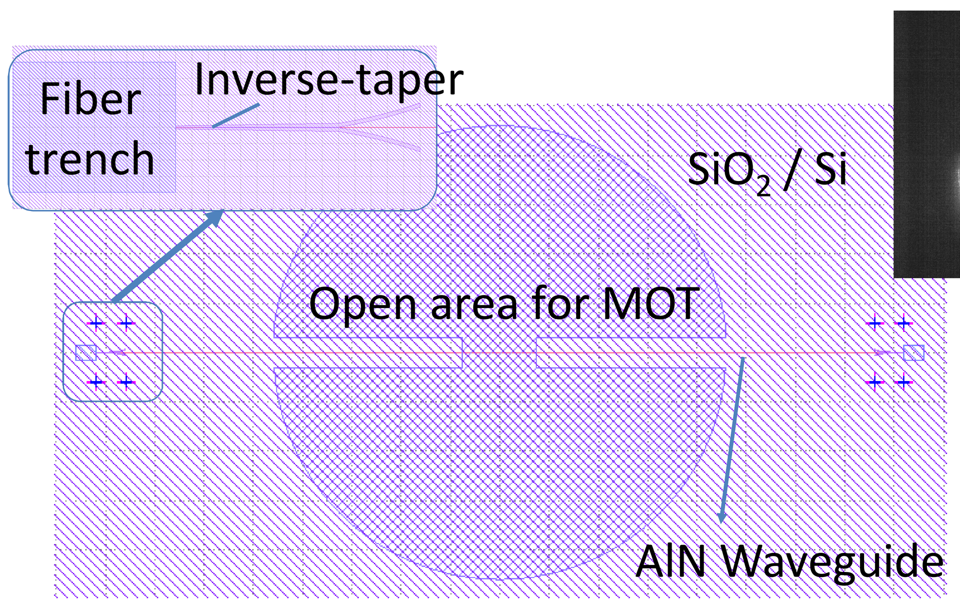
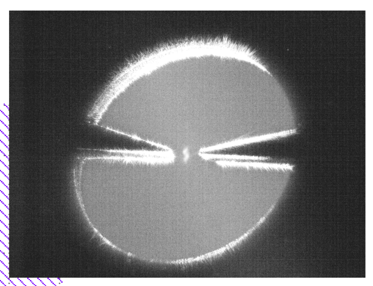


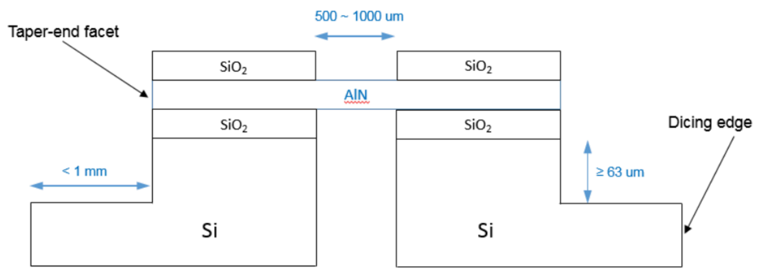
Image is of electron beam resist on silicon nitride. Devices will now be plasma etched and released (KOH).

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

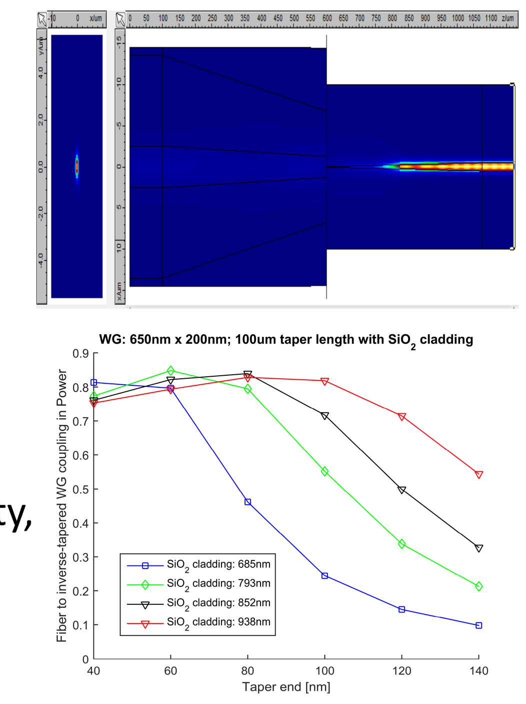
Fiber-to-WG butt-coupling + MOT in a needle



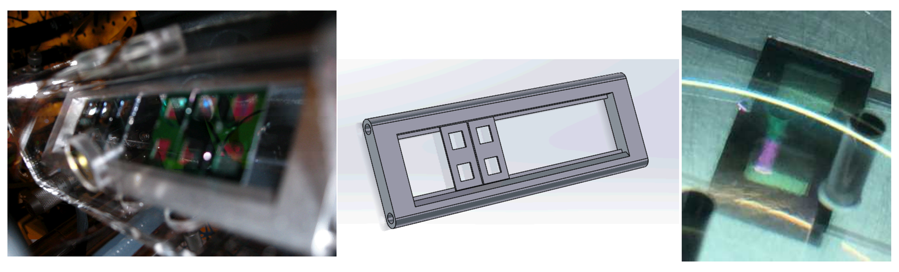




- Open needle structure for MOT atoms
- Inverse-tapered butt-coupling for 685, 852, 938nm lights
- Oxide cladding for better heat dissipation, mechanical stability, and lower propagation loss
- AlN WG with better thermal conductance than SiNx WG
- Photo-lithography + e-beam lithography for taper etching



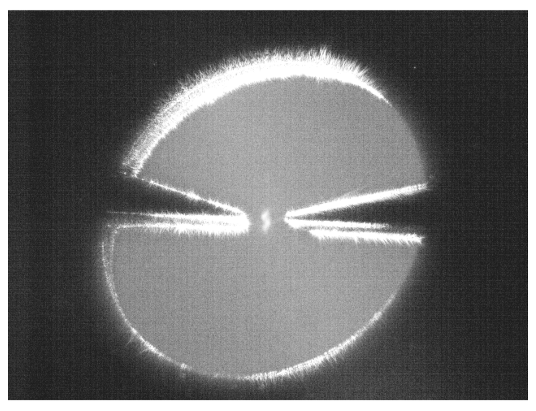
MOT test in AlN / SiNx membrane



- AlN and SiNx fabricated membrane structures
- 400µm, 600µm, 1mm diameter hole
- 400µm, 600µm, 1mm diameter hole with 3µm width dummy waveguide
- How much cold atoms (sub-Doppler cooling)?
- How many atoms?

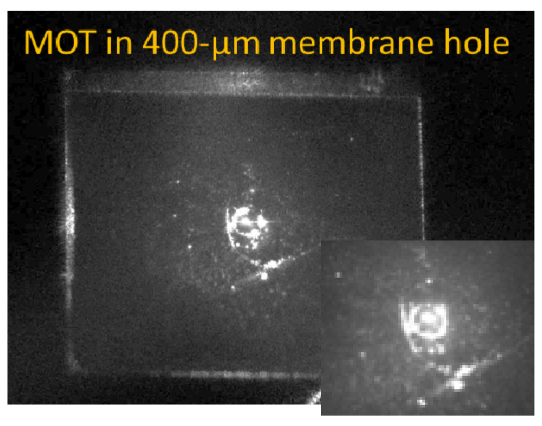
MOT clouds inside fabricated structures

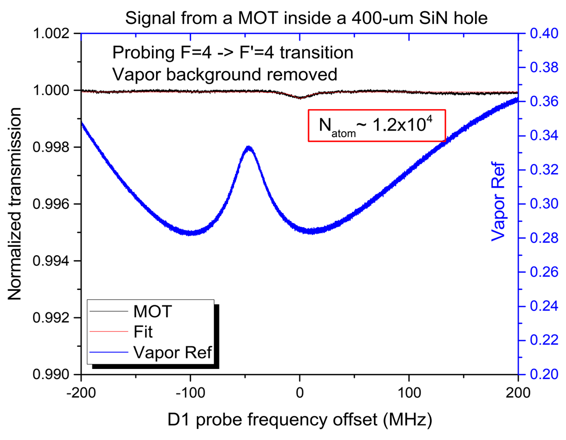
Si needle structure



- Cold atoms (Cs) in 750-µm gap Si needle structure

SiN membrane

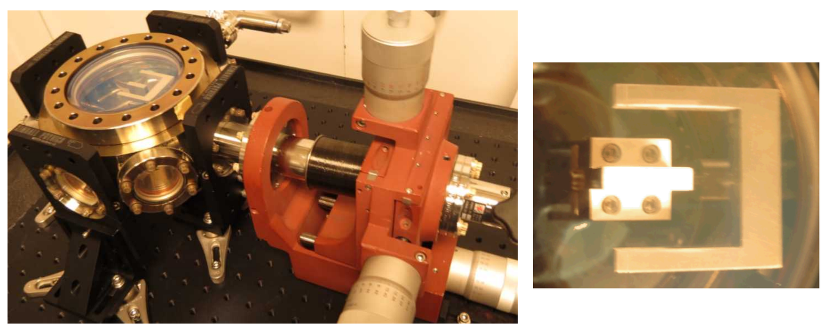




- The 400-µm hole has a 3 µm x 125 nm dummy waveguide
- We have demonstrated more than 10000 cold atoms inside a 400-µm SiN membrane hole.

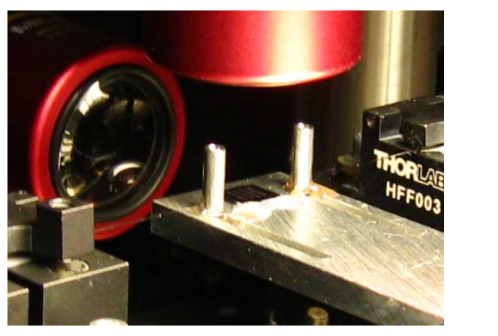
AlN / SiNx WG test in a vacuum

Vacuum chamber with a 3D sample stage



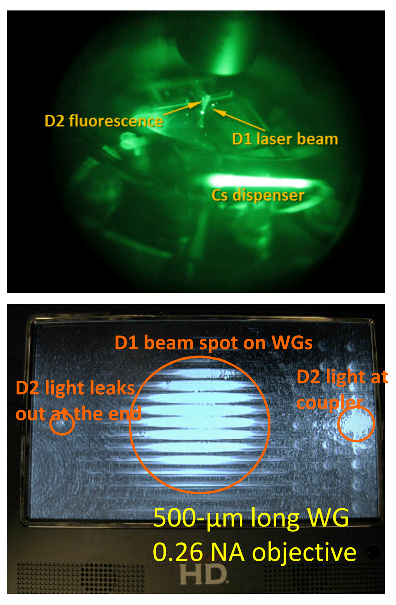
- Testing AlN and SiNx waveguides in vacuum
- How much optical power to those WGs in vacuum?

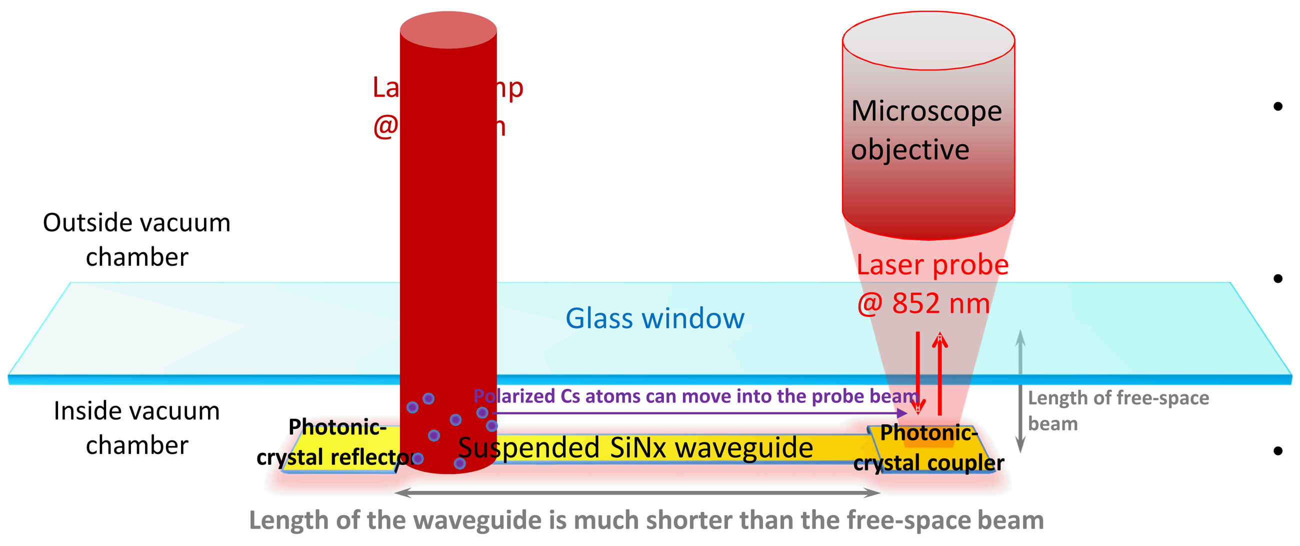
Pre-aligned and glued dimple fiber



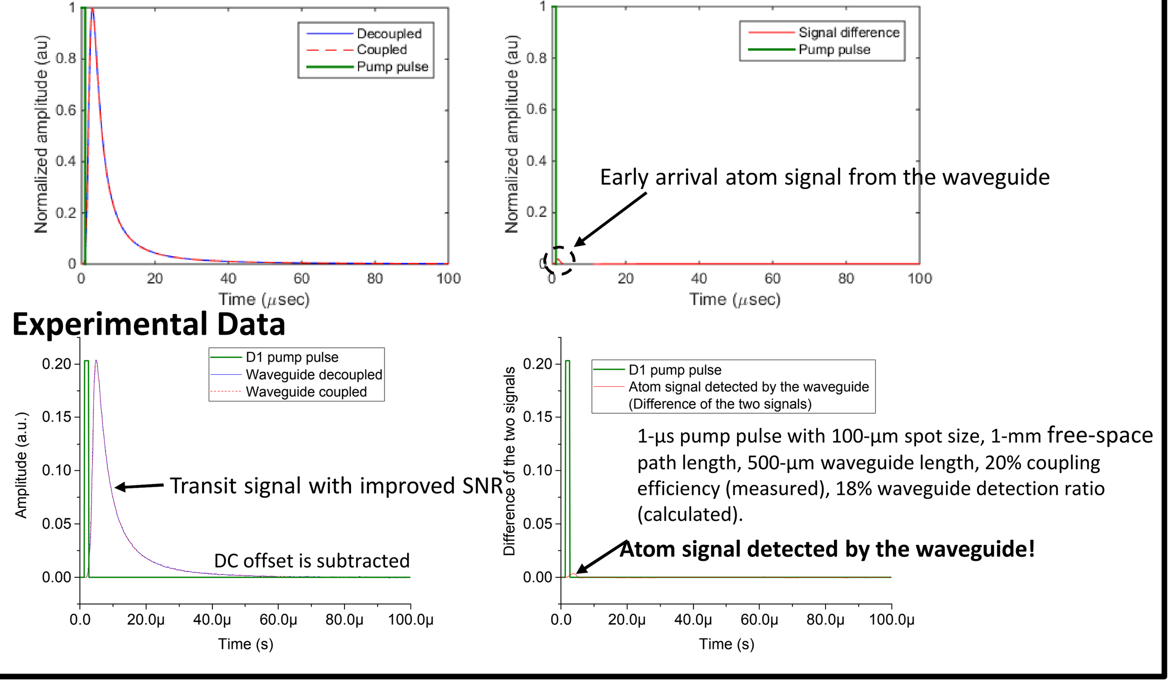
- A pre-aligned and glued dimple fiber coupled to WG is glued on two posts before transferring it to a vacuum.
- Vibration-induced decoupling decreases the light coupling to WG.

Detection of thermal Cs atom signals through waveguides





- The probe beam 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.
- 125-µm long WG, 0.4 NA objective, 50 µW probe laser power @ 852 nm Cs D2 transition



Sandia National Laboratories is operated and managed by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc. National Technology and Engineering Solutions of Sandia operates Sandia National Laboratories as a contractor for the U.S. Department of Energy's National Nuclear Security Administration (NNSA) and supports numerous federal, state, and local government agencies, companies, and organizations.