High Resolution Photonic MKID Spectrograph

M. Daal[1], Renan Moreira[2] , J. Bailey[1], and B. A. Mazin[1]
[1] *University of California, Santa Barbara,* [2] *Ultra-low Loss Technologies*

Mazin Lab
All of the wavelengths
All of the times
mazinlab.org

SPECIFICATIONS

Make a single mode fiber (SMF) fed spectrometer, R~5,000, suitable for use at any large telescope where the light is channelized by a photonic circuit chip and then detected by a separate chip with an energy-resolving superconducting detector (MKID) array.

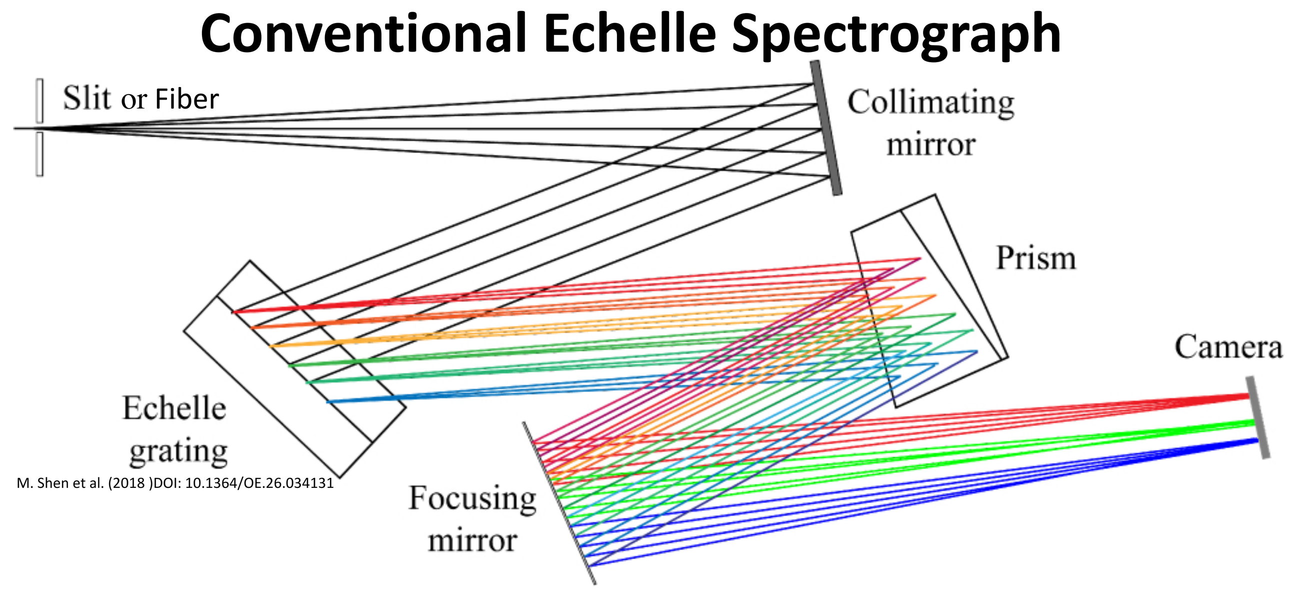
- Wavelength Range: 400 – 800 nm
- Free Spectral Range: $\sim$ 100 nm
- Number of Channels: $\gtrsim$ 1024
- Chan-to-Chan Extinction Ratio: $\gtrsim$ 30 dB
- Photonic and MKID Chip areas: $\gtrsim$ 4 cm^2 each
- Operation Temp: $\approx$ 100 mK
- Throughput (Fiber to MKID): 60%

Ultimate Goal: MMF/SMF fed high resolution spectrometer on a single chip integrating LTD and photonic circuit.

WHY PHOTONICS?

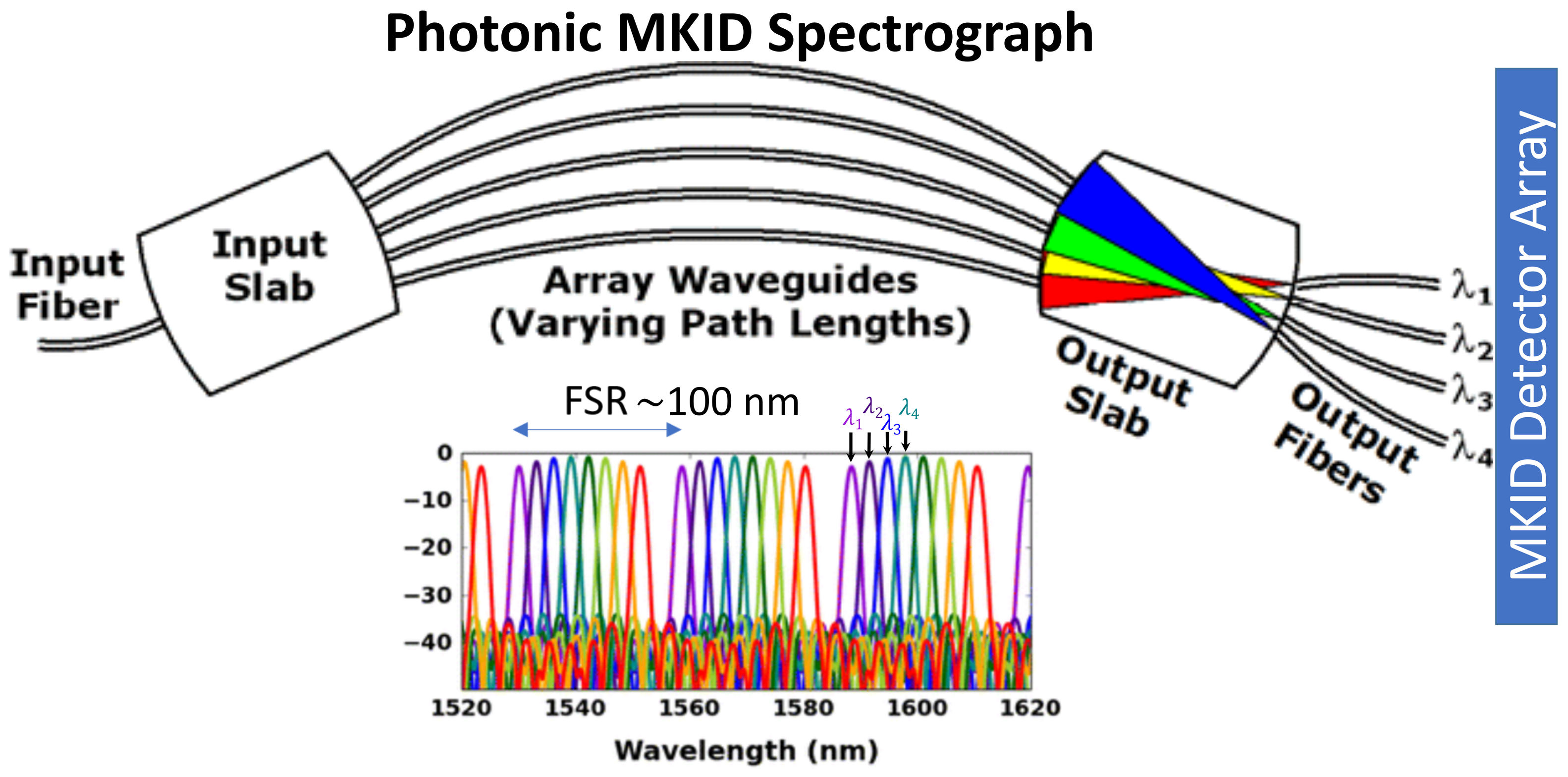
Photonics: Devices that make use of optical waveguides or other structures or materials that can manipulate properties of light such as phase and direction.

Conventional Echelle Spectrograph



- Use adaptive optics of telescopes to format light in to single mode fiber (or MMF + Lantern)
- Photonic circuits puts conventional spectrograph collimator, disburser and camera optics on a few cm^2 chip
- Small size avoids thermal and vibration deflections
- SMF stabilize instrument response to input beam illumination fluctuations (e.g. pointing induced), a.k.a. 'Spatial Filtering'
- Spectrometer's component sizes no longer scale with telescope aperture
- Fiber feed avoids cryostat windows
- Cheaper after technology development investment
- Multiple spectrograph chips enable integral field or multi-object format

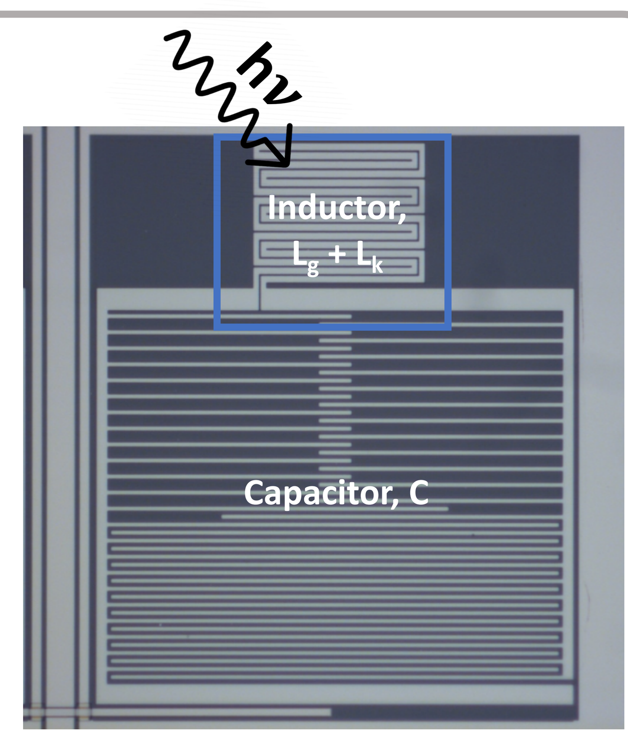
Photonic MKID Spectrograph



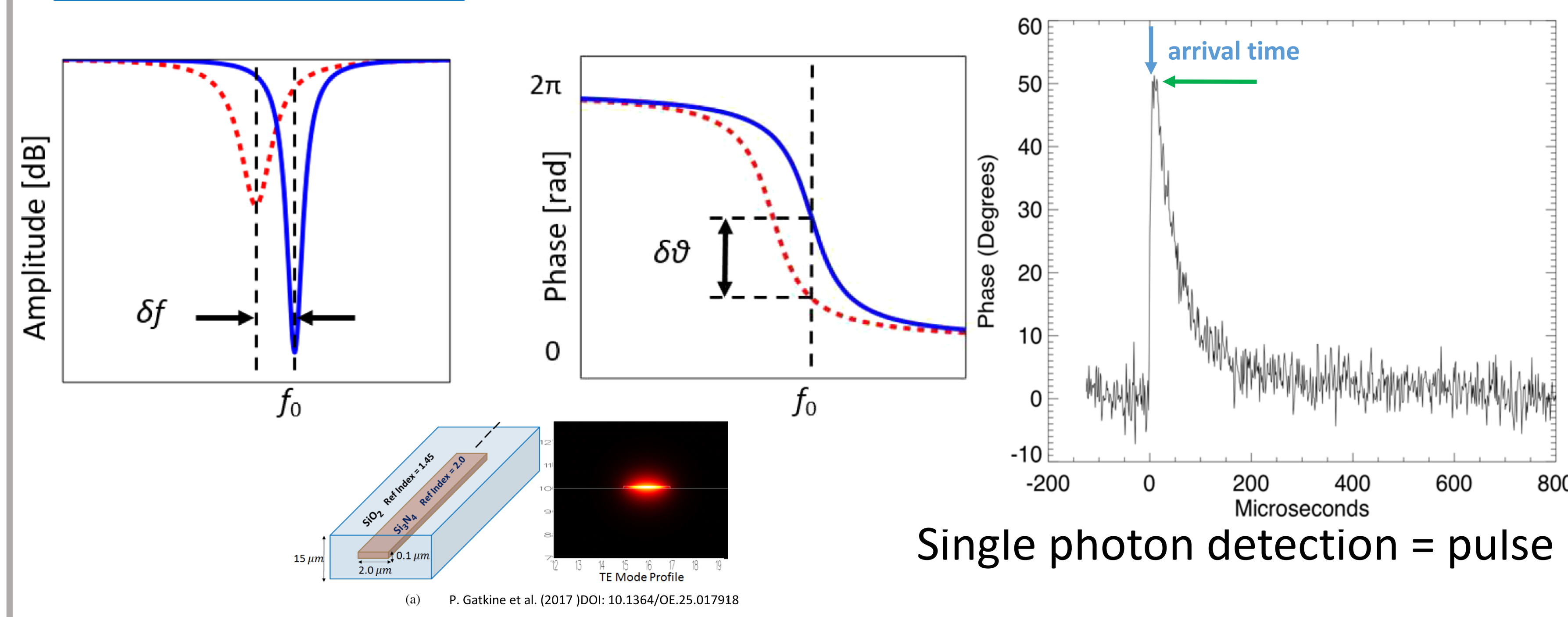
'Arrayed Waveguide Gratings' acting as filter bank put light in to N channel centered at λ_i, $\Delta\lambda$ wide, and, spectral resolution $R = {}^{\lambda}/_{\Delta\lambda} = {}^{E}/_{\Delta E}$, FSR apart. However, each channel contains many orders: nλ_i, $(n+1)\lambda_i$, $(n+2)\lambda_i$,⋯

MKIDs

- Can be operated in on Calorimetric or Bolometric modes
- Photons change surface impedance of superconductor, Lk
- Each photon creates phase pulse in calorimetric mode
- Possible to couple inductor to photons exiting output waveguides *or output waveguide evanescent waves*



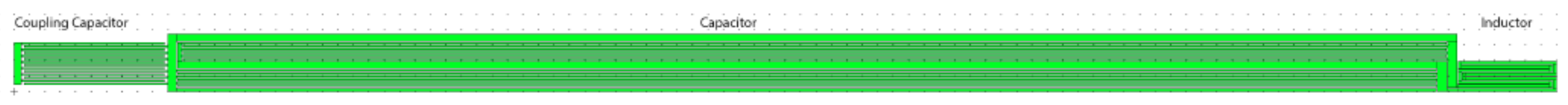
$$f_0 \propto \frac{1}{\sqrt{(L_g + L_k)C}}$$ → Change in L_k → Change in f_0 , Phase



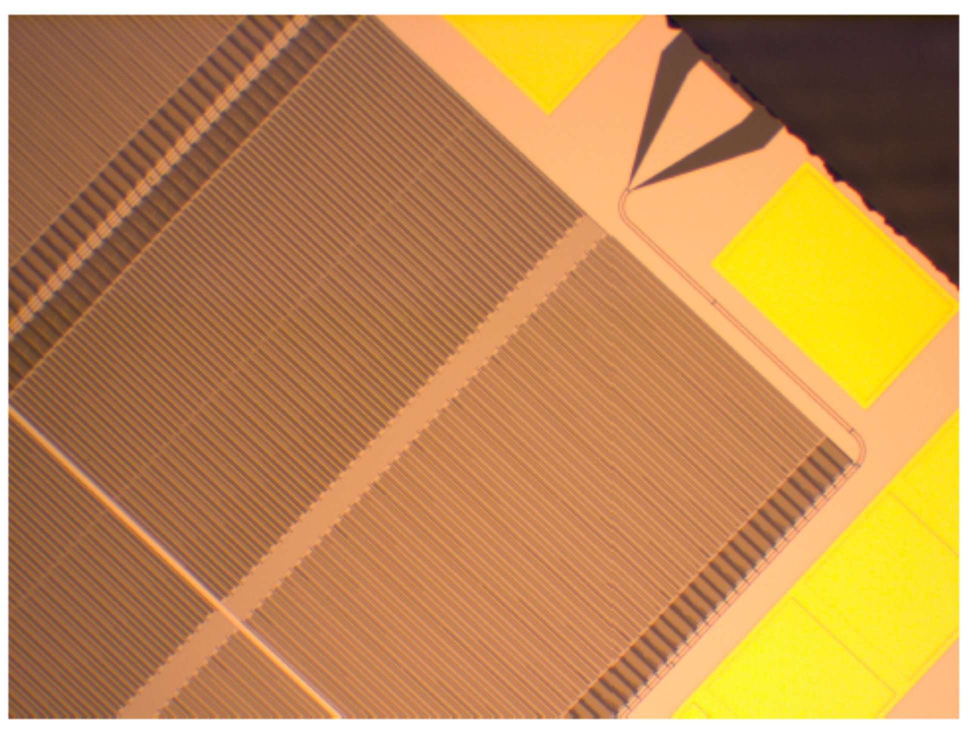
Single photon detection = pulse

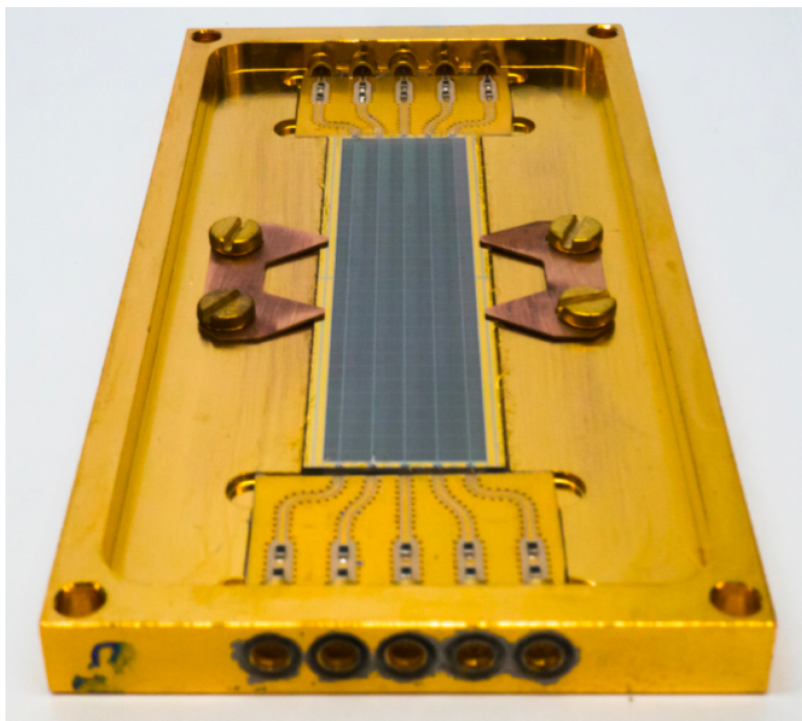
Could couple to light within waveguide . . .

WHY MKIDS?



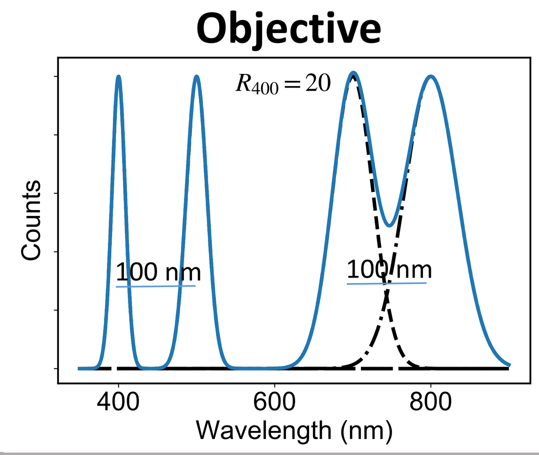
- The MKID is necessary to:
- Exploit multiplexibility to obtain thousands channels
- Use intrinsic energy resolution to sort the orders in each output channel of the photonic circuit. Target: 3 – 5 orders sorted
- Single photon sensitivity, lack of read noise and integration time enable time resolved spectroscopy and high sensitivity to faint objects
- Miniaturization afforded by ability to position detectors only at out channel locations



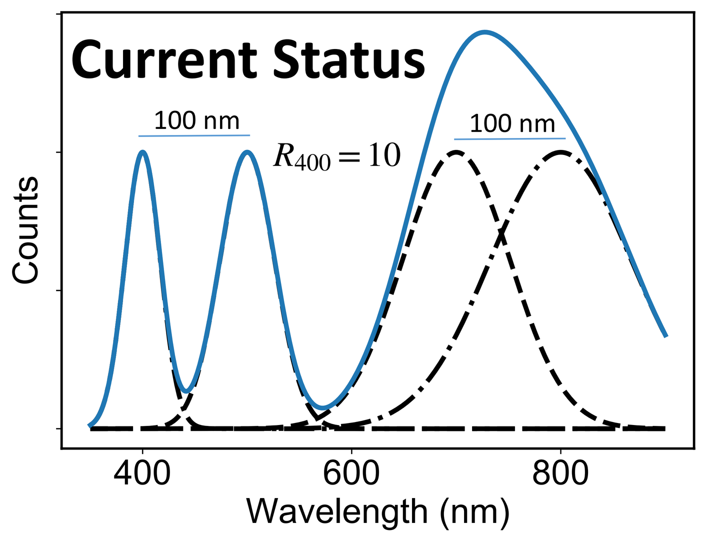


Linear Detector array:
5 rows of 2048 MIKDS
Pixels:
20 μm pitch, 65 μm wide, 4 μm gap
MKID Sensor:
PtSi ($R_{400} \approx 8$),
Hf ($R_{400} \approx 10$)
Anti-reflective coatings:
SiO_2/Ta_5O_2

Objective



Current Status



RESEARCH TASKS

- Measure optical properties of photonic circuitry test at < 1 K
- Photonic circuit design incorporating above
- Photonic circuit to MIKD chip butt coupling design and test at < 1 K
- Demonstration of spectrum from known source

18th International Workshop on Low Temperature Detectors, Poster #378 *July 21th – 26th 2019, Milano*