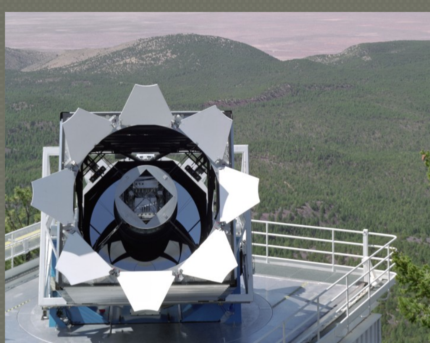
Development of an MKIDs instrument for SOAR

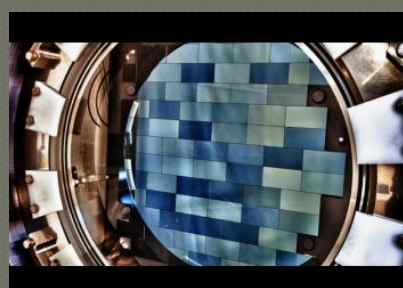
Juan Estrada
Aug-2013

FNAL interest

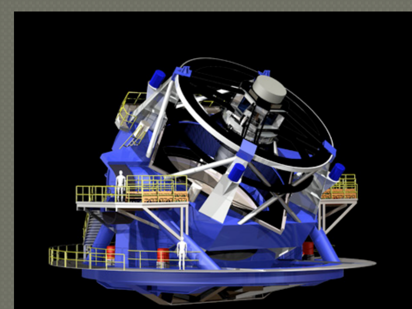
- FNAL has a rich history on astronomical surveys for cosmology:



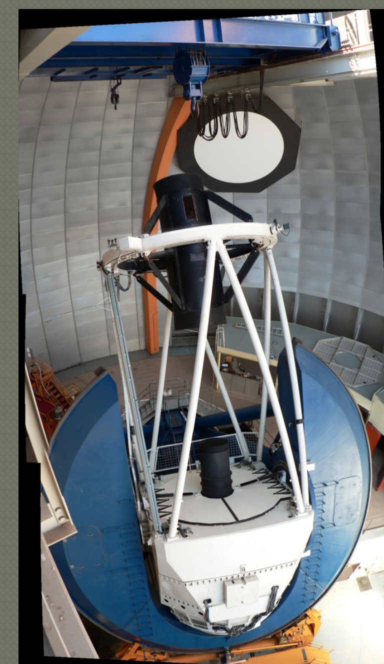
SDSS



DES

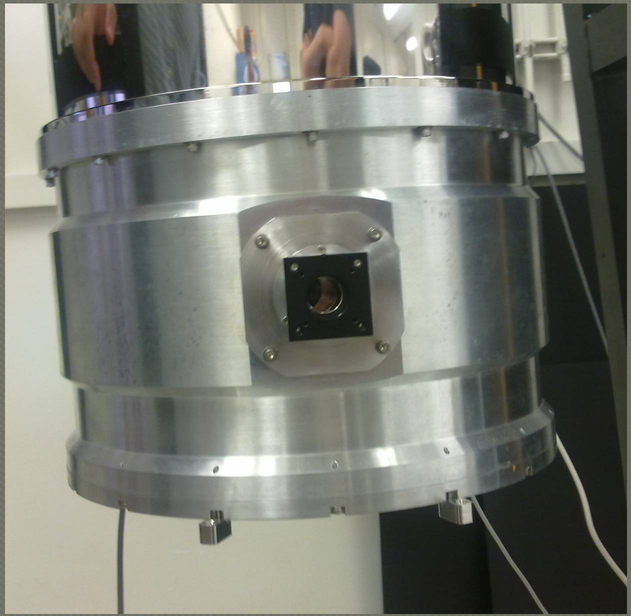


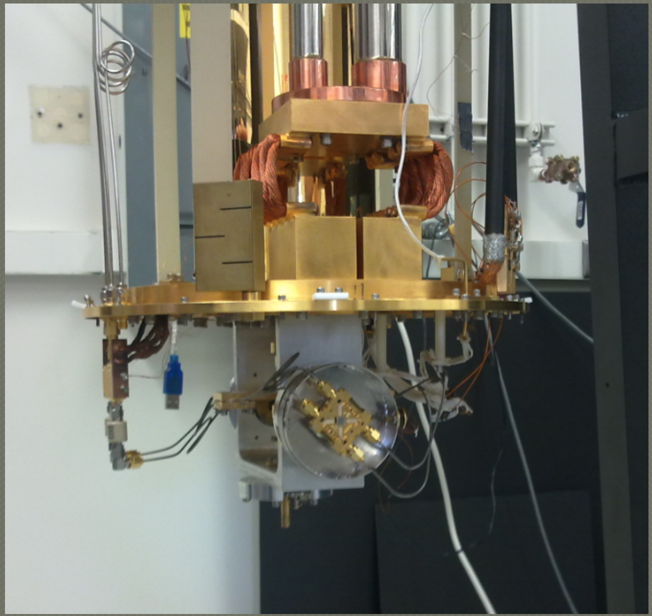
LSST



DESpec

ARCONS





UCSB has installed an instrument with 1k and 2k arrays in telescopes.
FNAL is interesting in helping moving this forward into larger arrays.

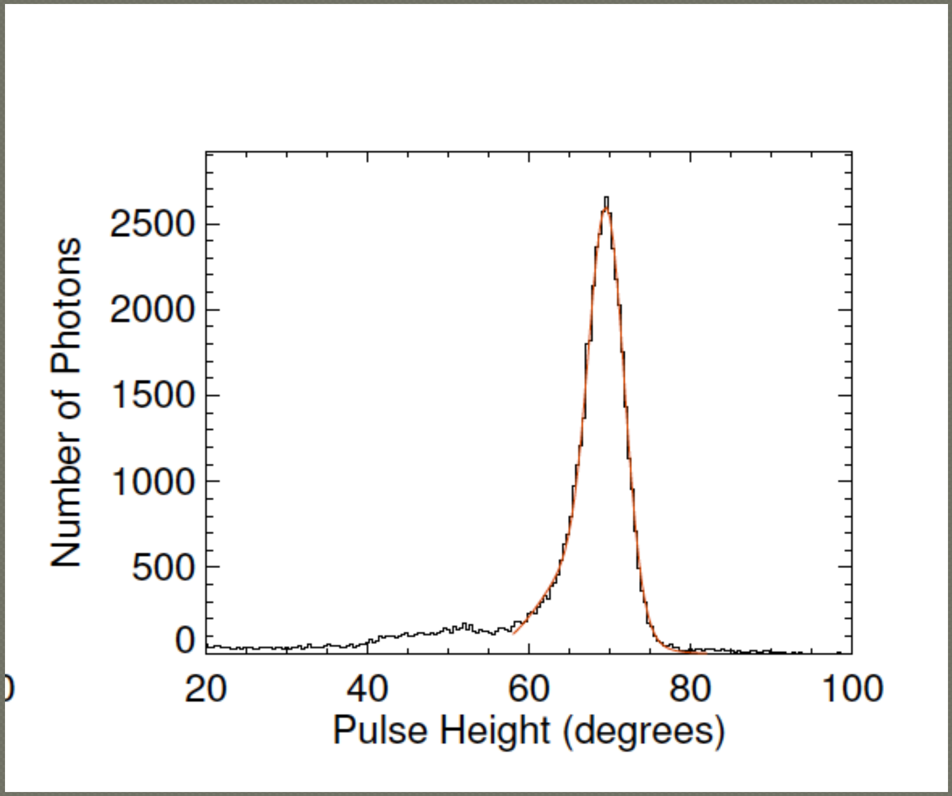
Energy resolution

- MKIDs not ideal yet

R= E/ δ E = 16 @250nm

Theoretical limit for the MKIDs is R=180… there is still ways to go.

More on Gaston's talk.



LIFE is not perfect yet….

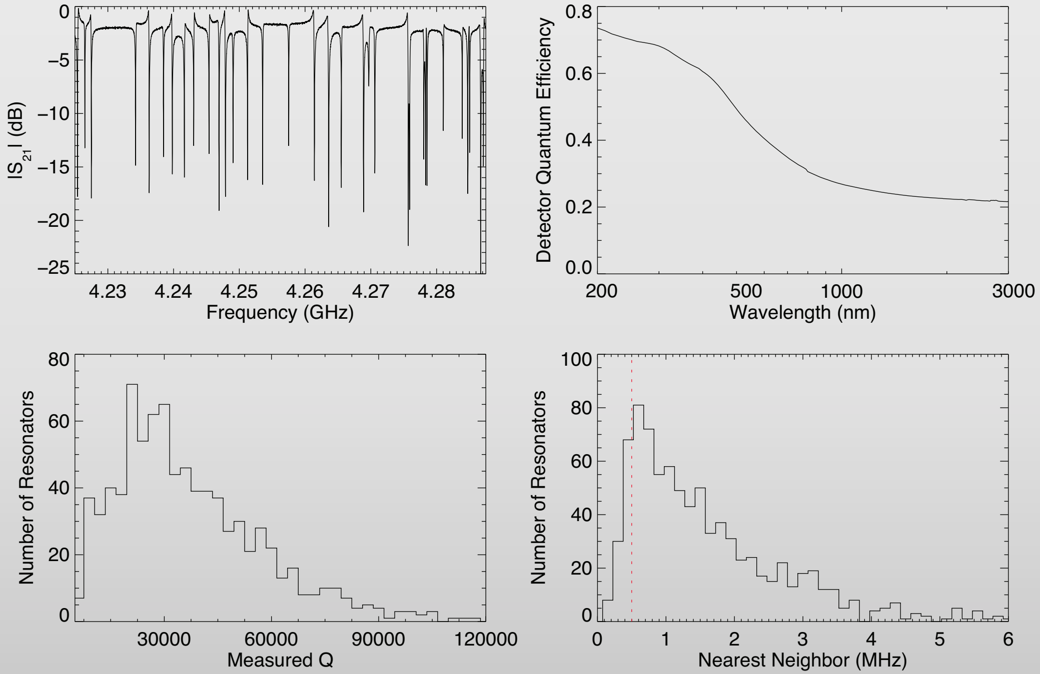


Fig. 5. The top left panel shows the microwave transmission through the device over 10% of the frequency span covered by resonators. The top right panel is a measurement of the quantum efficiency of a bare 40 nm TiN on sapphire film. The bottom left panel is a histogram of measured quality factor for 852 out of a possible 1024 resonators. The internal quality factor of the resonators, $1/Q_i = 1/Q_m - 1/Q_c$, was approximately 1×10^6. The bottom right panel is the frequency spacing in MHz between each resonator and its nearest neighbor. Most of the missing resonators are too close together in frequency ($<$ 500 kHz, noted with a dashed line), resulting in only one resonator being included in the plot.

Challenges for survey instrument

- Device fabrication:
  - Energy resolution (R)
  - Amplifier noise – HEMT
  - Frequency spacing control (85% channel yield)

- System integration :
  - Detector packaging/connectors/cabling
  - Cryogenics – thermal budget
  - Warm readout electronics – channel count

Challenges for survey instrument

- Device fabrication:
  - Energy resolution (R)
  - Amplifier noise – HEMT
  - Frequency spacing control (85% channel yield)

This is not our area of expertise. We will probably contribute as we learn about the detectors, but we are relying on UCSB to focus on these issues.

Challenges for survey instrument

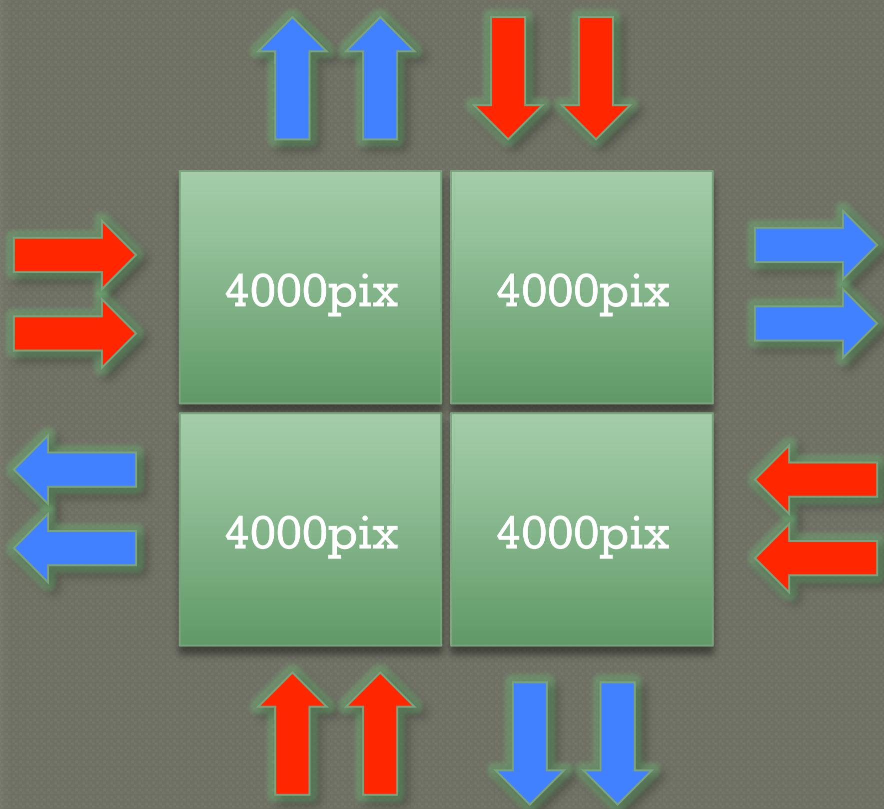
- System integration :
  - Detector packaging/connectors/cabling
  - Cryogenics – thermal budget
  - Warm readout electronics – channel count

This is our area of expertise.

As a baseline we are thinking about an instrument 10 times larger than ARCONS.

System Integration Challenges

Packaging



Buttable detector :

UCSB is now building a 2k sensor with 2 feed lines. They believe they could do 4k with 2 feed lines.

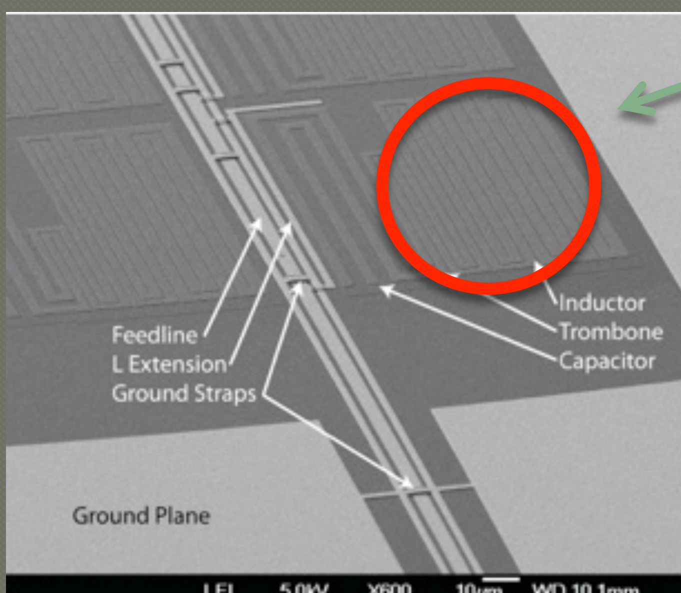
We want to start thinking now on a possible mosaic with MKIDs.

One could probably survive without this for a while, but it will be needed eventually and is good to start understanding it. It also gives much higher flexibility for our next R&D instrument.

Packaging: Micro-optics

from the ARCONS 2012 paper

> are physically far apart. To improve the quantum efficiency of the device a 100 μm pitch circular microlens array is used to focus the incoming light on the inductor, since photons hitting the capacitor or wiring will not be detected or will appear as photon events with an energy significantly below their true energy. The circular microlenses used in these measurements limits the effective fill factor to 67%. An improved lens with square lens elements could increase the fill factor above 95%.



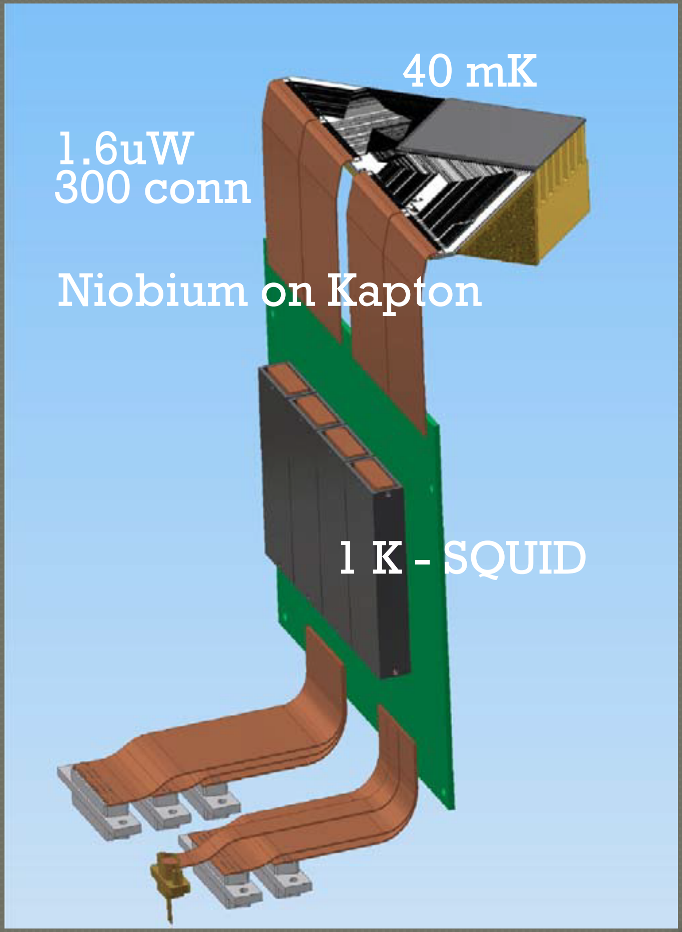
Light has to get here and a microlens array is used for this. There is some optimization that can be done to improve efficiency in this area.

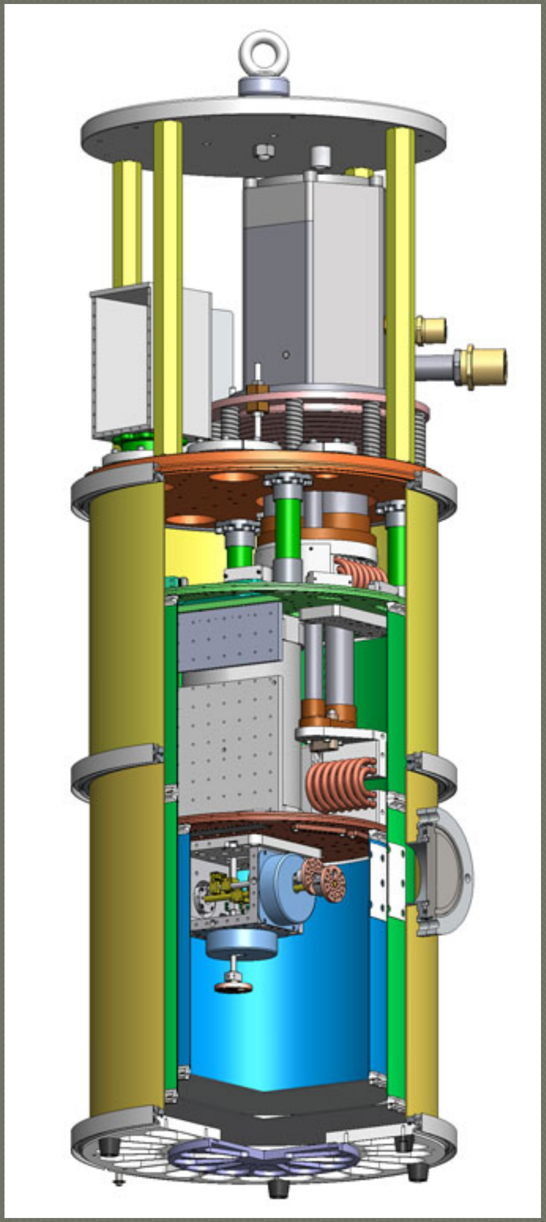
Packg: Connector/Cables

- Now:
  - Discrete semi-rigid coax cables for all feed lines. The cables are big, delicate and the main thermal load.
- Future:
  - Superconductor flex circuit
  - UCSB group is already thinking about this.

See talk by Greg Derylo on Pack +integration

SCUBA2 solution





HPD ADR (DRY) Cryostat
Capacity: 118 mJ

This should allow us to cooldown an array with 10 feedlines (5 devices in their current configuration) using commercial coax cables.

This would only be possible with the proper heat sinking at 1K (also 5K and 60K).

Vacuum fredthrough: 5 sq-inch

Heat load for 5 Detectors

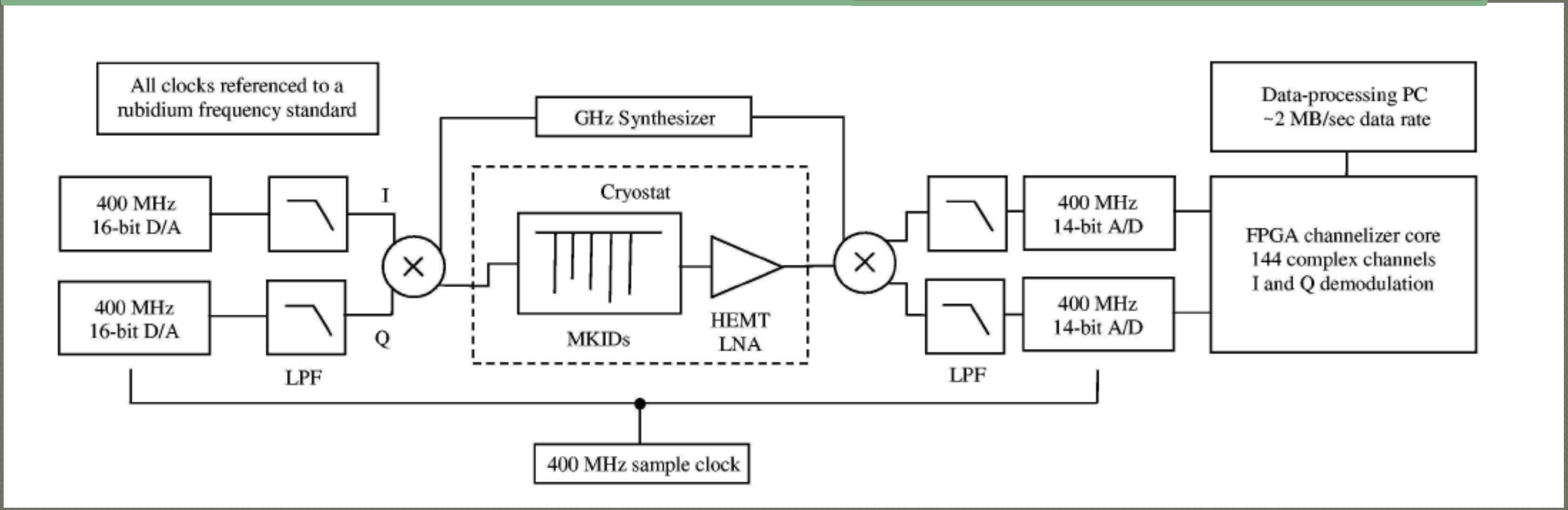
20 Cables = 1.7 microwatts
window and surfaces =0.16 microwatts
Vacuum at e-6 torr = ? Microwatts
1 temp sensor = ? Microwatts

Estimated run time with 118mJ capacity
= 18 hrs before a 3 hr regeneration is needed

Herman Cease
Fermilab Mechanical Development Group

warm electronics

Comb Generation	Detector GHz	Warm electronics Lower frequency



The problem here is that you have to digitize a fast signal. The faster you can sample the more channel you can read.

warm electronics

A solution exists to readout 512 channels per feedline (ARCONS), and maybe a solution is possible to readout more (2000?).

from the ARCONS 2012 paper

> resonator fitting in a 100×100 μm square. Due to bandwidth limitations of our electronics we use two feedlines to read out the array, each serving 512 resonators. The resonators are designed to be separated by 2 MHz within a 4–5 GHz band.

See talk by Gustavo Cancelo

Plan-2013

Getting started:

- Establish mK lab at FNAL:
  - ADR received in April 2013
  - Operations without problem
- First MKID readout
  - Received an MKID from ANL and operated Aug-2013
  - Readout with Network analyzer done Aug 2013
  - Readout with Roach by summer 2013 ← **we are here**
- Readout of UCSB array
  - Detector arriving this week (maybe)
  - Fully instrumented in the fridge by fall 2013
- Start optical testing of MKID
  - Optical window (copy UCSB design) fall 2013
  - Develop optical bench for QE and spot projection – late 2013
  - Start using Spot-projector from Umich at FNAL – early 2014

This is our Lab today.
Need to integrate optical bench + roach system

Plan-2014

- By early 2014 we expect to be in conditions to make progress:
  - Detailed optical testing of UCSB arrays (response vs wavelength and location in the array)
  - Upgrading of signal path in ROACH system

  (fast ADC already being tested by Gustavo's group)
  - Larger focal plane. Ben keep telling us that he can make larger arrays, we always say we want to use several of his large arrays. We will see how this works out at the end.

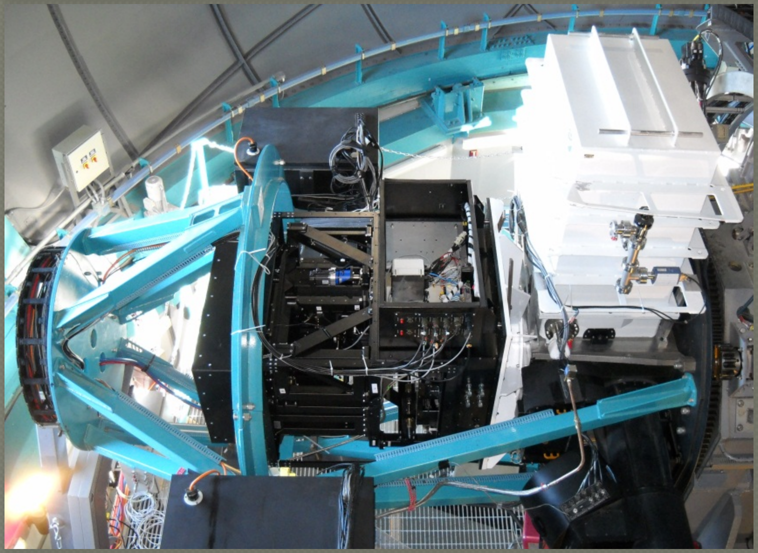
- By the end of 2014 we would like to be seriously considering a first test in a telescope with some of the new developments.

Where could we go?

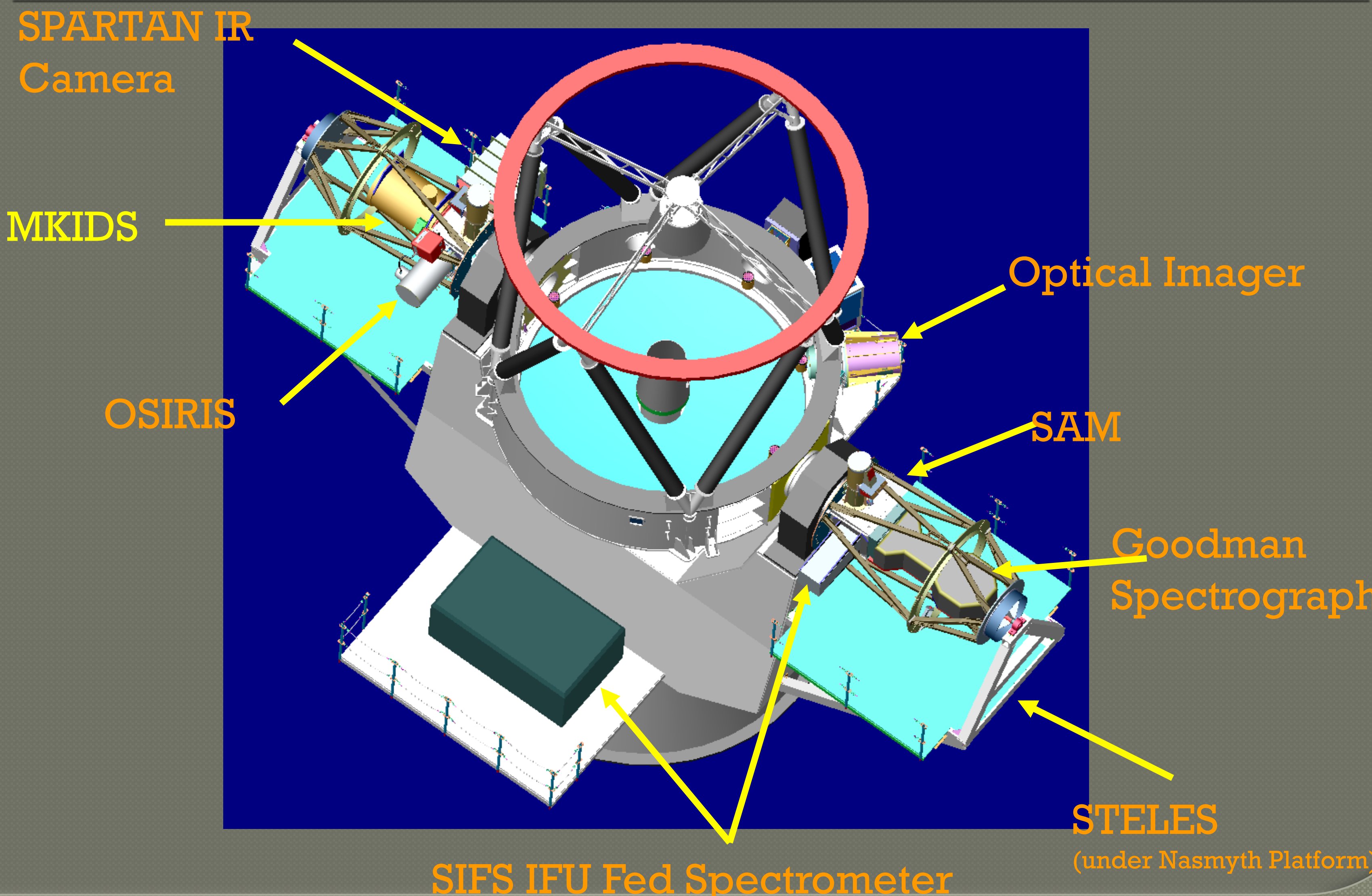
Blanco 4m telescope
The house of DECam

30 minutes drive from Blanco y SOAR
Also part of the "same" organization.
This is a modern 4m telescope

ADR can not tilt
MKIDS Goes Here



SOAR Instruments



Conclusion

- Reasonable start at FNAL with this technology in 2013
- Now we want to start contributing to making real progress in the development of large instruments with MKIDs.

- Opinion:

  If there is a large instrument with MKIDs in the future, there is going to be only one. At least for a long time.

  The obvious: Try to avoid duplication, and coordinate R&D steps between the different groups to increase our chances of success.