CMB Polarization Research Program

Chao-Lin Kuo, Sarah Church, John Fox, Sami Tantawi, Jeff Neilson

KIPAC/SLAC

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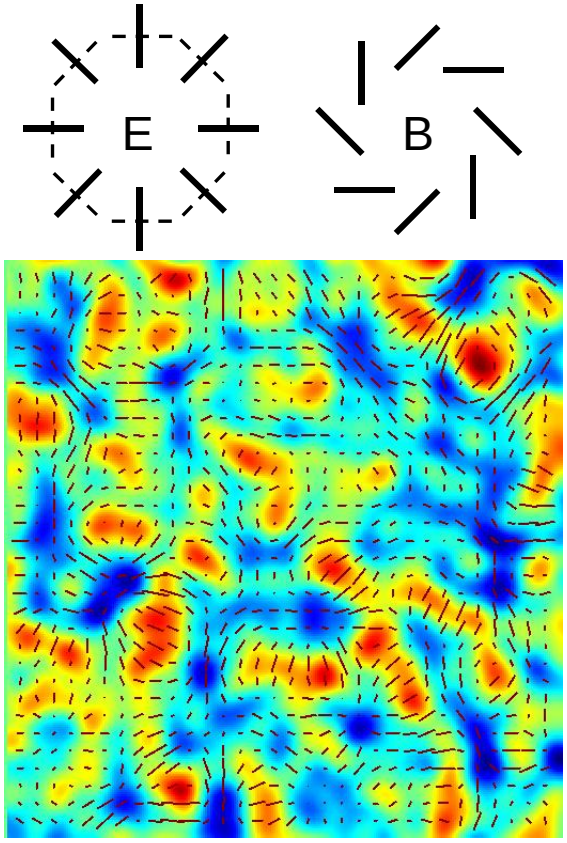
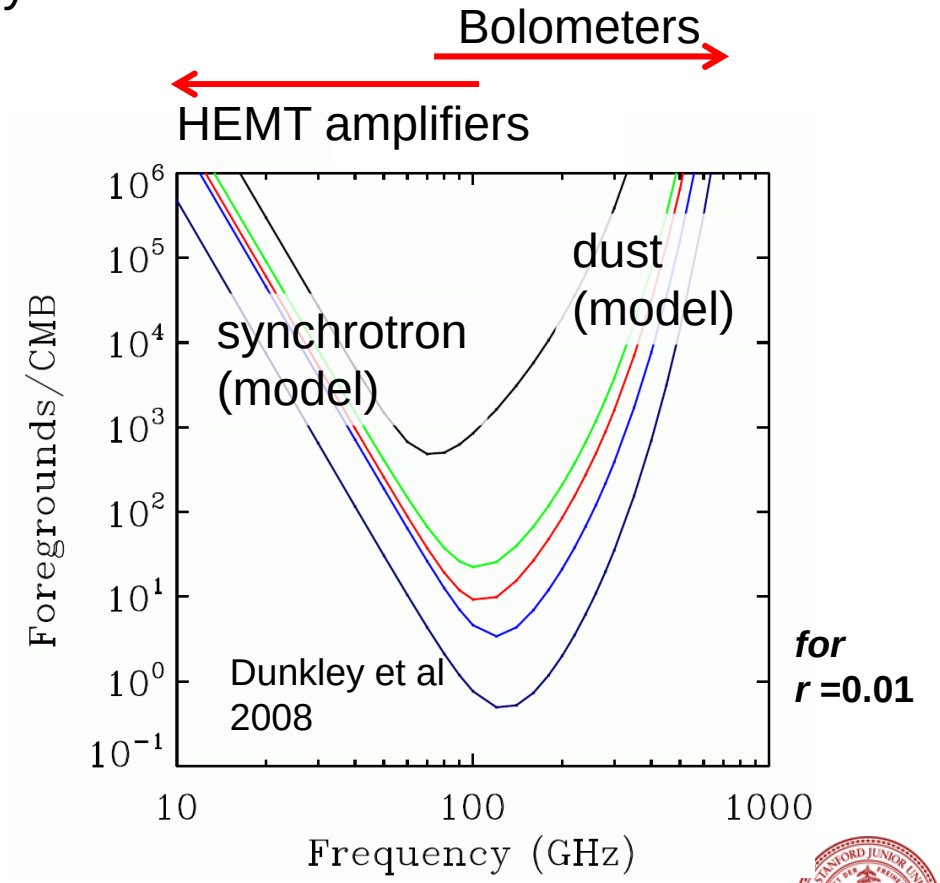
The *B*-mode Science

- The energy scale of Inflation (amplitude of the gravitational waves)
- The *absolute* mass of neutrino (down to 0.03 eV for ideal exp.)
- The early evolution of dark energy

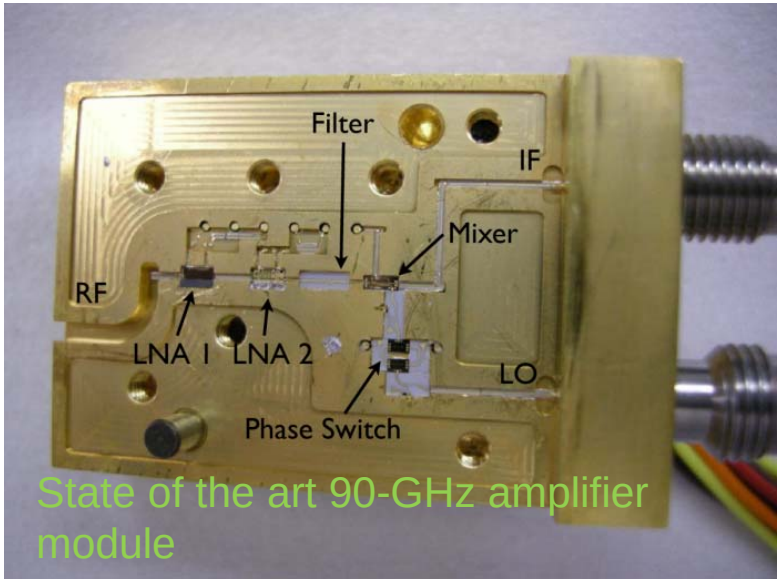




Previous work

MMIC HEMT amplifier arrays (LDRD award 2008-10)

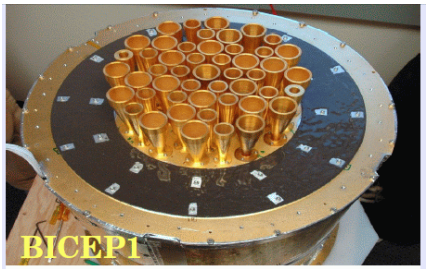
- Development of front-end detector technology, feeds and polarization splitters.
- Synergetic with SLAC expertise in RF/microwave technologies



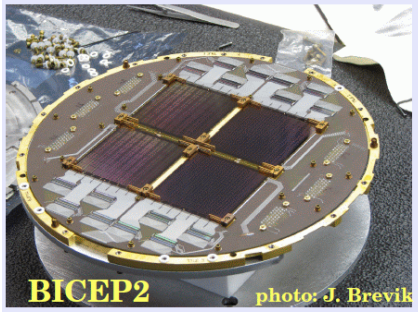
State of the art 90-GHz amplifier module

Collaboration with JPL, Caltech. Uses SLAC designed microwave filters and phase switches

BICEP/BICEP2/Keck (Bolometric)



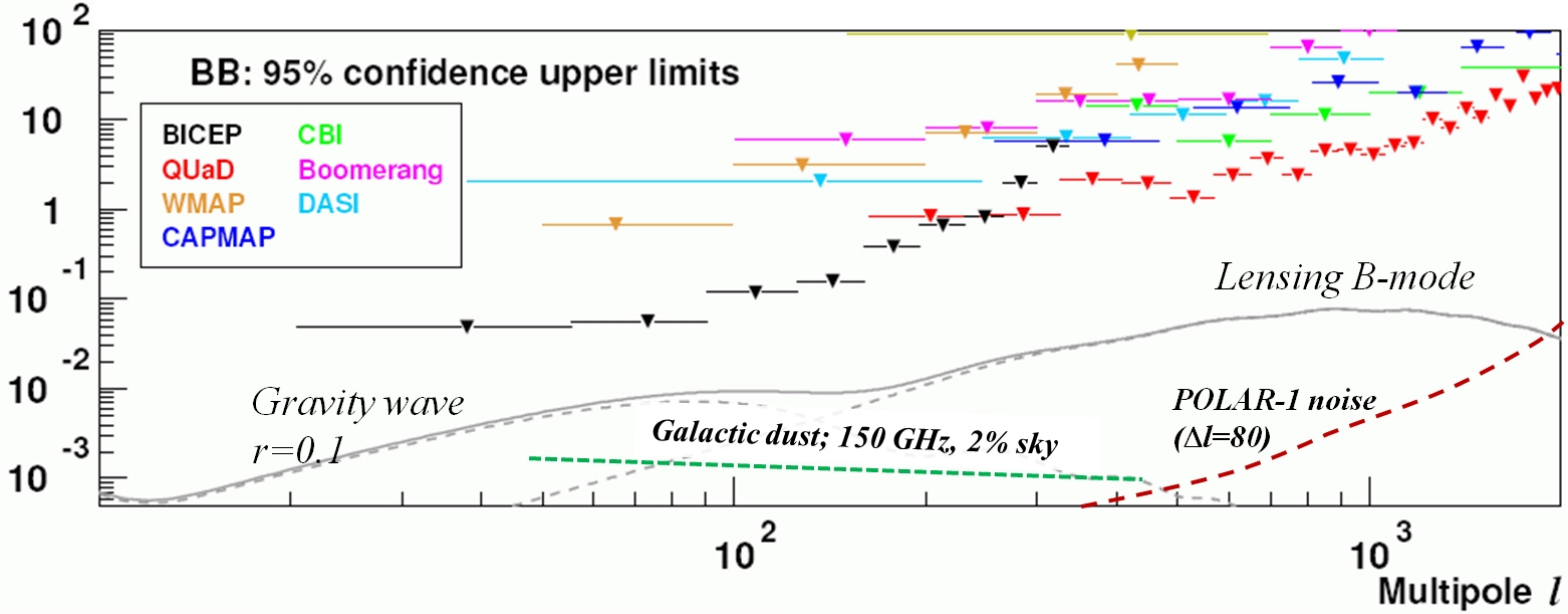
90/150GHz
25/24 elements
2005-2008



150GHz
256 elements
Taking data
(analysis partly supported by O&E)

150GHz
256x3(5) elements
Under construction
(integration partly supported by O&E)

KIPAC has a strong heritage in the field – BICEP(100/150GHz), QUaD(100/150 GHz), QUIET-I(40/90GHz)



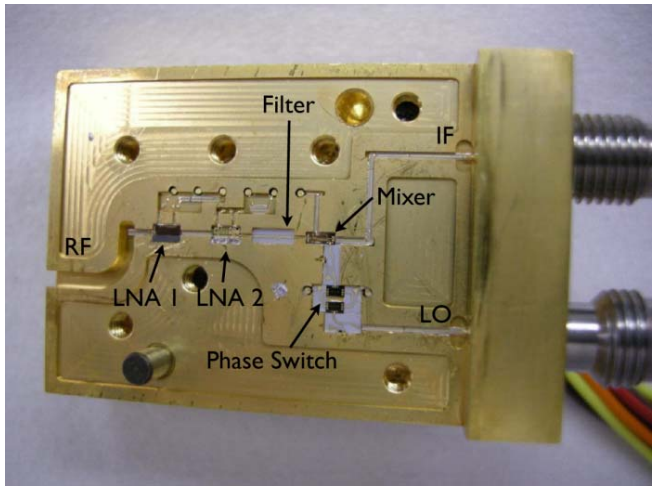
- KIPAC (campus funding) participated in QUIET (Co-I Church), building the 1.4m telescope, in BICEP (Co-I Kuo), and led the QUaD experiment (PI Church)
- BICEP provides the best limits on inflation energy. QUaD provides best limits to the lensing signal. QUIET-I (to be published) will provide similar sensitivity to the two.
- Great opportunities in (i) improving the limit on inflation (ii) exploiting lensing science
- The next experiments: *large* in scale, and/or technology intense – national lab involvement

Proposed SLAC role in QUIET: 32/44 GHz MMIC array development

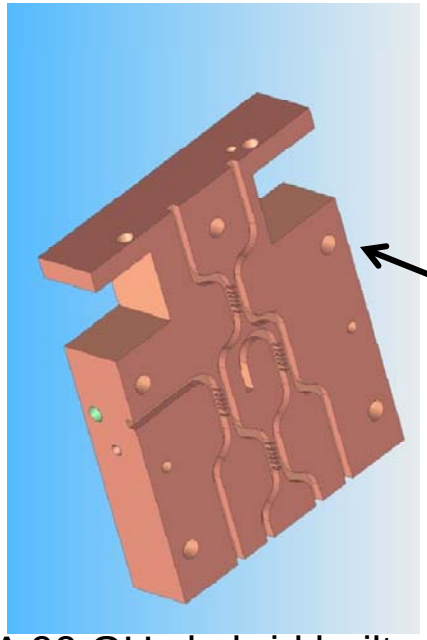
- **QUIET II -- search for gravitational waves produced by inflation (~10x sensitivity than QUIET-I)**
  - This experiment was considered by PASAG under CMB research
  - University of Chicago directed (Winstein NSF PI).
    - US and international involvement, including KEK (Japan)
    - Proposal to NSF submitted 2009. No official word, but NSF is requesting more work to improve detector performance.
  - Proposed DOE role (Fermilab and SLAC) would be to provide the detectors (MMIC amplifier modules) and other RF parts, participate in data handling and analysis.
- **Proposed SLAC (Tantawi, Church)**
  - Develop improved Q-band (44 GHz) module using more sensitive HEMT amplifiers (JPL)
  - Develop Ka-band (32 GHz) module
  - Build Q-Band, Ka Band feeds and polarization splitters
  - Complements a Fermilab proposal to provide W-band hardware (90 GHz).
  - Builds on the previous LDRD effort to apply SLAC RF expertise to MMIC amplifiers for CMB research; funds were also used to collaborate with JPL, Fermilab on W-band module improvements for QUIET II

Proposed SLAC role in QUIET: 32/44 GHz MMIC array development

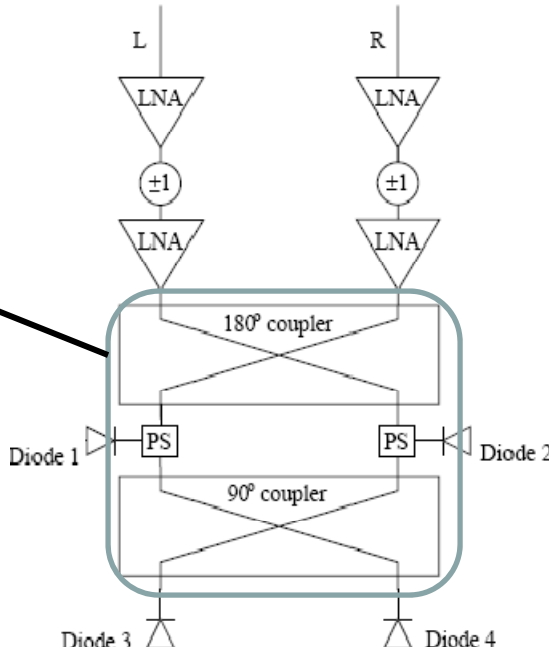
* Q-band (44 GHz) and Ka-band (30 GHz) are crucial frequencies for foreground removal from W-band (90 GHz) data



A 90 GHz prototype module (not QUIET design) for other CMB applications built by SLAC/campus in collaboration with JPL



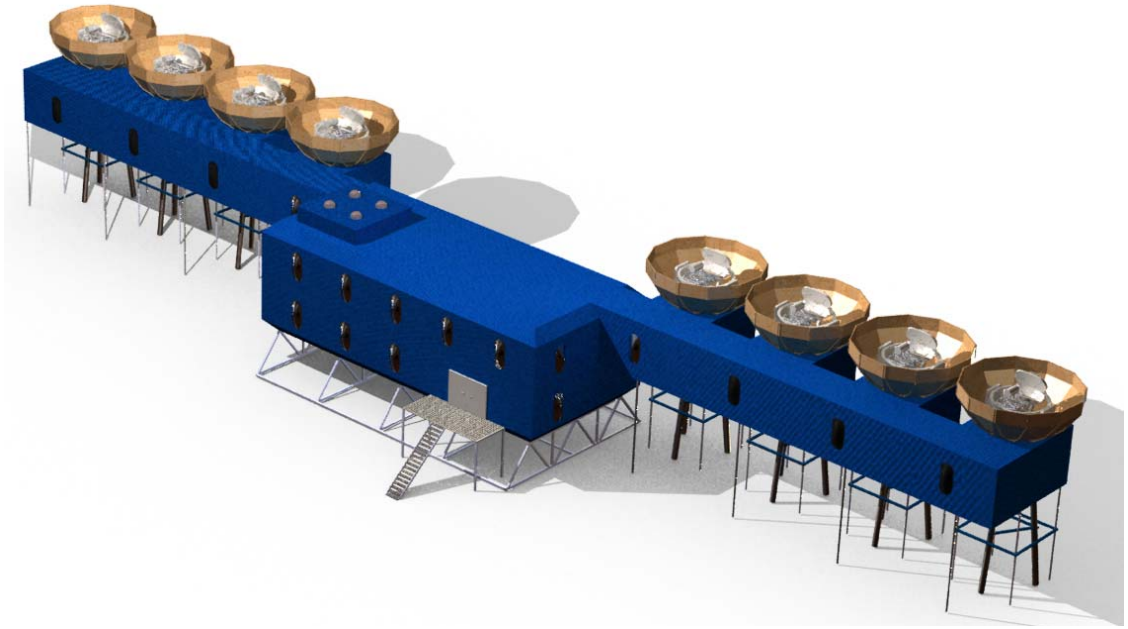
A 90 GHz hybrid built by SLAC to test QUIET modules



Block diagram for the QUIET radiometers

- Hardware and expertise already in place at SLAC to design, build and test prototype modules, feeds and polarization splitters

Lensing Science with the *POLAR Array*
(Ten 2m-class QUIET-style telescopes; 100-220 GHz)

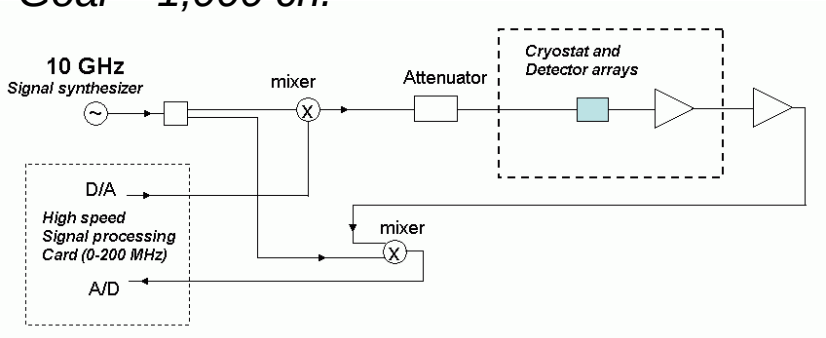


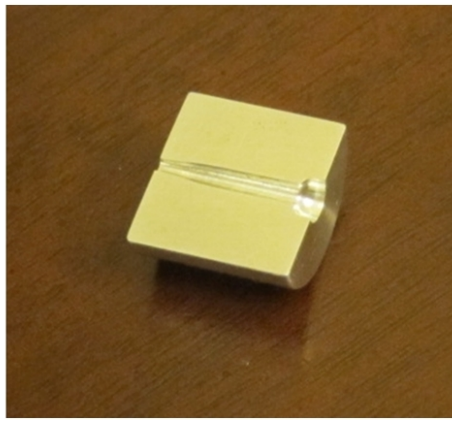
- Follow-up to ***SPTPOL*** (Argonne/U. Chicago; 2011); Complementary to ***QUIET-II***
- Two surveys (i) *DEEP* for inflationary gravity wave (ii) *WIDE* survey for lensing science
- The Pathfinder experiment (POLAR-1) funded by the NSF (PI Kuo) – 2012 deployment
- Taking advantage of the RF/microwave/digital electronics expertise at SLAC
- 3 years of technology development, 3 years of construction – fielding ~ 2016

Proposed POLAR Array Activities at SLAC

- Assessment of new detectors: Microwave Kinetic Inductance Detector (MKID) or Transition Edge Sensor integrated with MSQUID
- Assessment of novel focal plane architectures: Feedhorn and antenna design
- Development of High speed (GHz) frequency domain multiplexing
- Large aperture vacuum window/Infrared filtering development (frequency selective surfaces)

Frequency domain multiplexing electronics
Currently: 256 ch. per pair of cables/card,
Goal = 1,000 ch.





Two possible focal plane technologies for POLAR: planar antenna(left) and feedhorn (right)

Manpower

- Previous work supported by LDRD, O&E/KIPAC
  - Senior:
    - Sarah Church (group leader: QUIETI/II, MMIC)
    - John Fox (digital electronics)
    - Jeff Neilson (RF/Microwave)
    - Chao-Lin Kuo (group leader: BICEP2/Keck/POLAR)
    - Sami Tantawi (group leader: RF/microwave)
  - Postdoc: R.Walter Ogburn (BICEP2/Keck)
  - Graduate Student: James Tolan (Keck)
- Issues
  - Schedule for HEMT testing is very dependent on FY 11 funding profile
    - SLAC personnel on HEMT program supported by LDRD that ended Sept 2010
  - Retention of expertise depends on FY11-FY12 funding