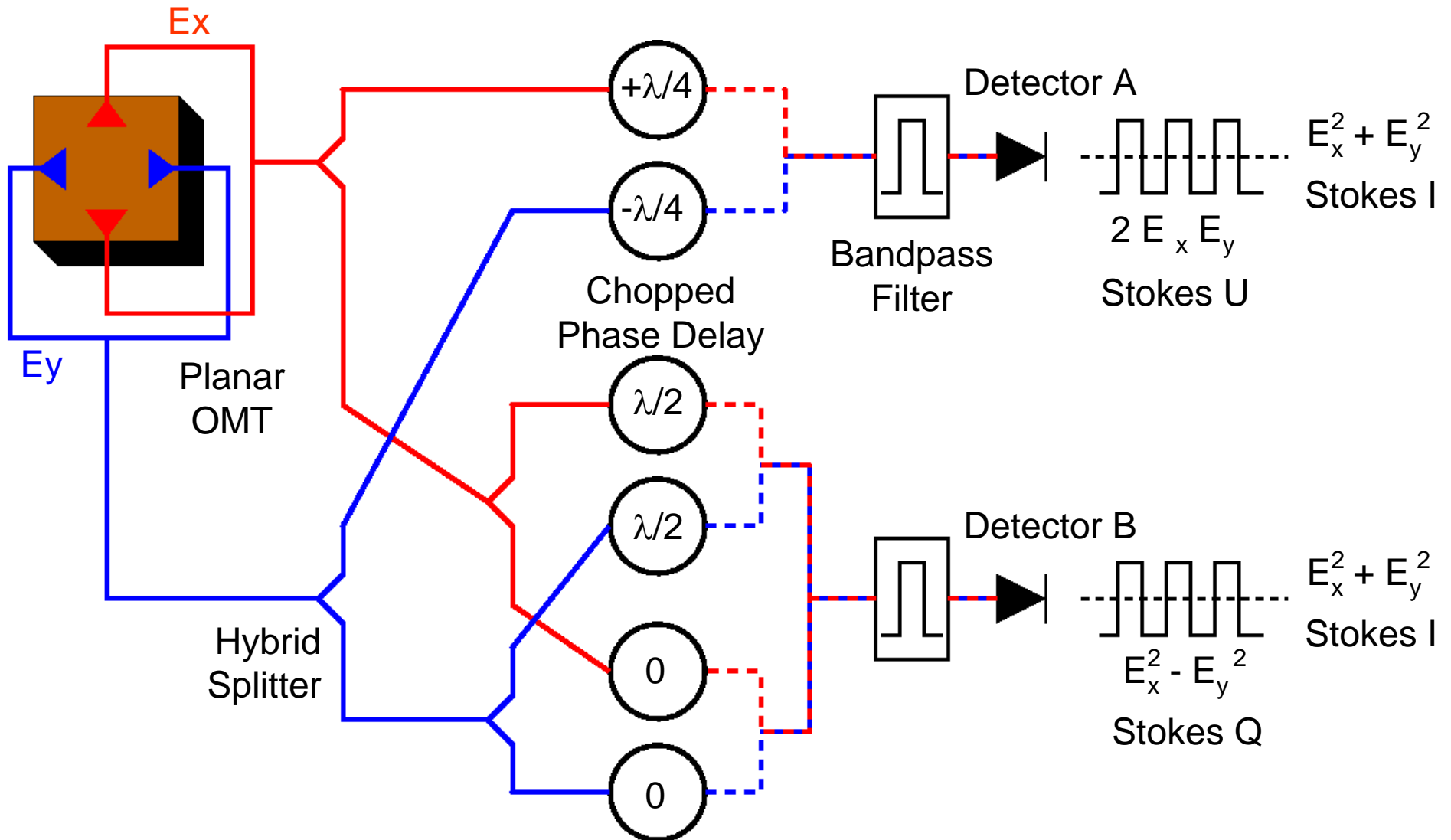
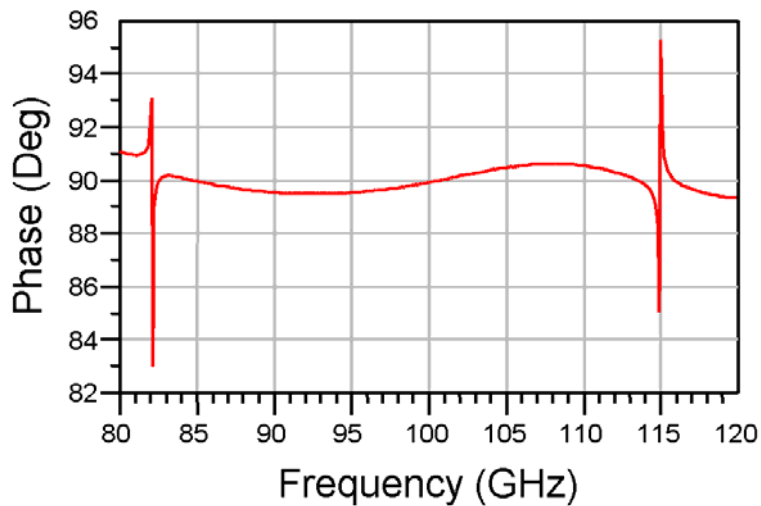
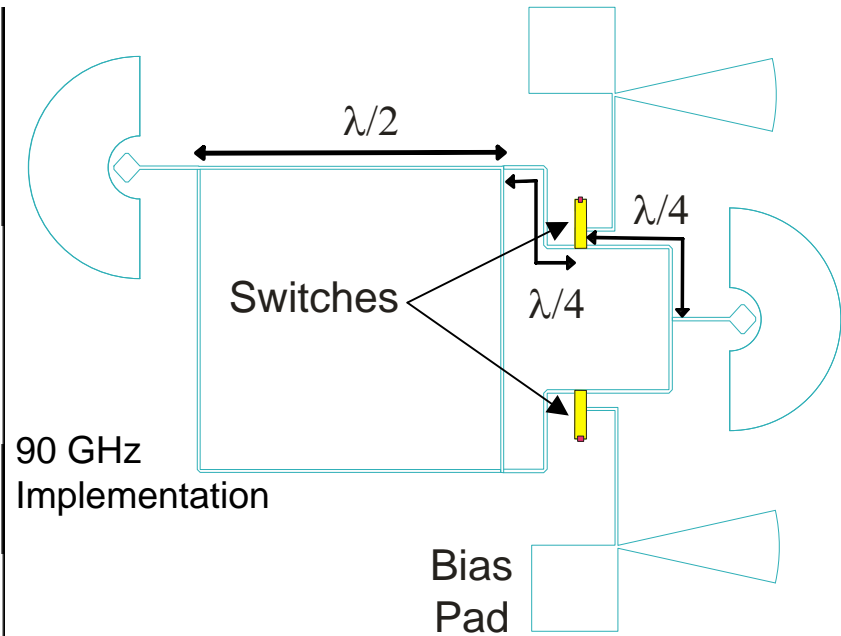
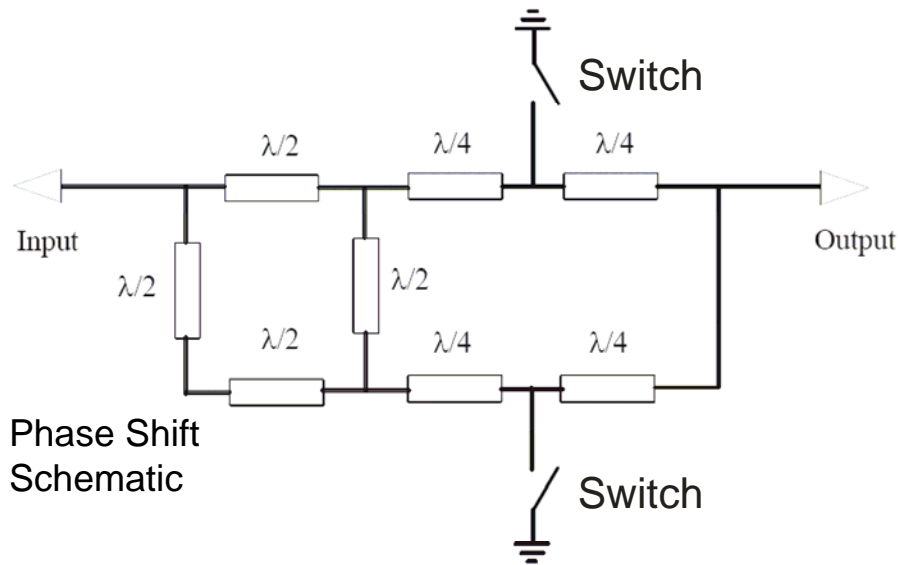


Photolithographic Modulators

Polarimeter On A Chip



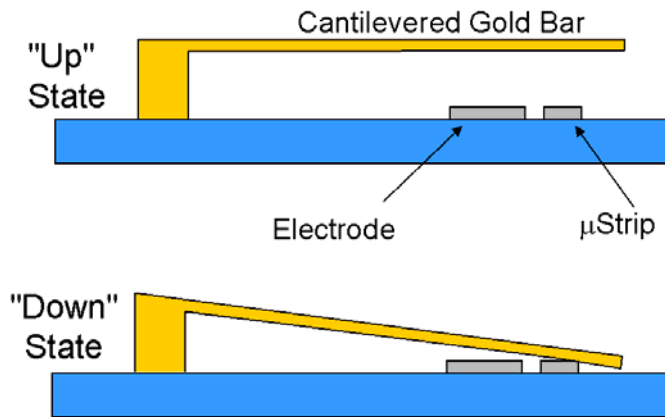
Modulator Circuit



Use switches to short out lengths of microstrip transmission line

Circuit tuned to achieve good phase stability over 30% bandwidth

MEMS Switch



Apply voltage to electrode to pull down gold bar cantilevered above microstrip

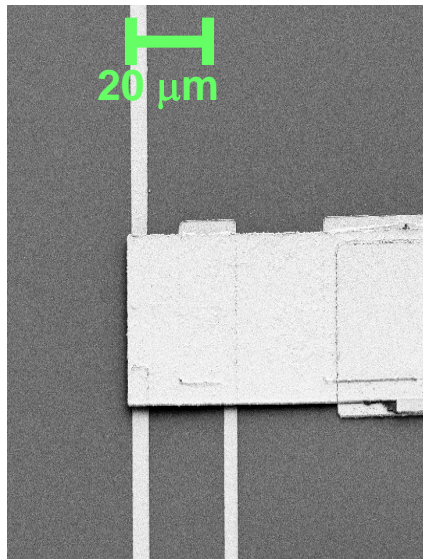
- Ohmic version (contact)
- Capacitive version (no contact)

Commercial versions available to ~20 GHz

Prototypes under development for CMBPOL

- Demonstrated at 90 GHz
- Design for 200 GHz

Transmission
Line
Electrode



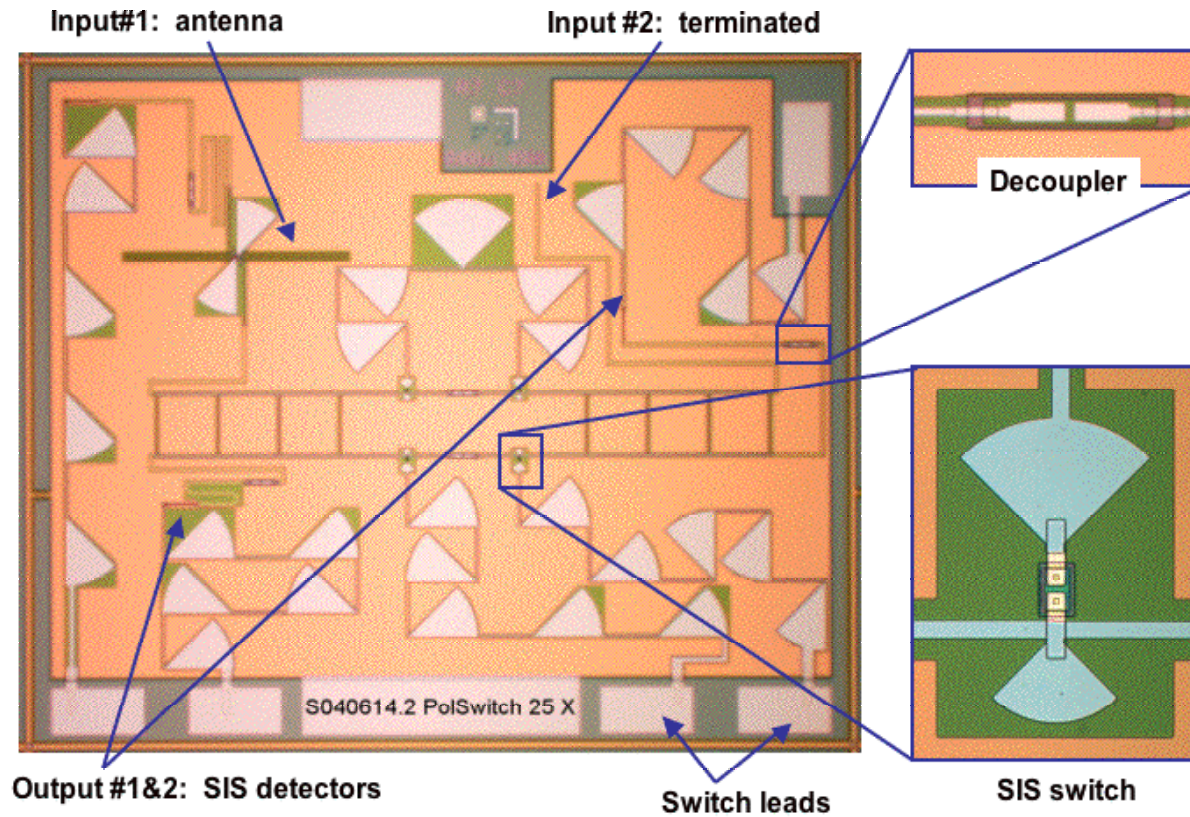
Advantages:

- Very fast (0.1 to 10 kHz)
- Demonstrated at GHz frequencies

Disadvantage:

- Fabrication is difficult
- Lifetime 10^{10} cycles not demonstrated

SIS Switch



Advantages:

- No power dissipated on cold stage
- No moving parts

Disadvantages:

- Smaller change in RF properties
- Harder to get wide bandwidth

Pros and Cons

Advantages

- Fast Modulation
 - 100 Hz to ~10 kHz
 - Fast compared to 1/f or beam motion
 - Nearly diagonal pixel covariance matrix
- Adaptability
 - No constraints on optical design
 - Useful from dc to >300 GHz
- Scalable Technology
 - Fully photolithographic
 - IQU polarimeter on a chip
- Repeatability
 - Minimal device-to-device variability
 - Minimize systematics from asymmetries
- Cryogenic Reliability
 - No macroscopic moving parts

Disadvantages

- Instrumental Systematics
 - Not the first optical element
 - Modulates sky and instrument polarization
- Fabrication Complexity
 - Adds 10--20 steps to photolithography
 - Higher fabrication costs
 - Lower yields
- Circuit Complexity
 - Careful circuit design needed
 - Slow design-test-evaluate cycle
- Power dissipation
 - MEMS power dissipated on 100 mK stage
 - Trade-off power vs switch speed

Current Technological Readiness

TRL 3: Component-level proof-of-concept

- Individual components tested in simple configurations
- Switch operation, phase circuit design & evaluation
- Beginning mm-wave measurements of phase switch circuit
- Commercial MEMS switches flown on ARCADE CMB balloon

But ...

- Not tested with TES bolometer detectors
- Not optimized for power dissipation
- Polarization modulators not yet flown on any instrument

Future Development

Minimal development activity at present

- Small GSFC/UVA program for MEMS switches
- JPL program for SIS switches terminated in 2005

Costs to get to TRL 5: 4 years development

- \$400 K per year procurement
- 1 FTE per year for circuit design
- 2 FTE per year for fabrication
- 1 FTE per year for testing

Time and cost are dominated by fabrication life cycle