



Berkeley
Wireless Research Center

86118A Sampling Scope Remote Head Module Teardown

Kunmo Kim

Version 1: 10/19/2023
Revised: 10/16/2025

Some photos appeared on RFIC, but my name didn't appear on the photo

RFIC

Time Domain Measurement Limits

Patent Number: 4,956,568 [22] Filed: Dec. 8, 1988
Date of Patent: Sep. 11, 1990

Non-Linear Transmission Line

Graph: Input (Diode 20) and Output (Diode 50) Volts vs Time, ps. The input is a trapezoidal pulse, and the output shows sharp spikes at the edges.

RFIC

Sampling Head Architecture

[Kunmo Kim - Berkeley]

[Kunmo Kim - Berkeley]

Graph: Input (Diode 20) and Output (Diode 50) Volts vs Time, ps. The input is a trapezoidal pulse, and the output shows sharp spikes at the edges.

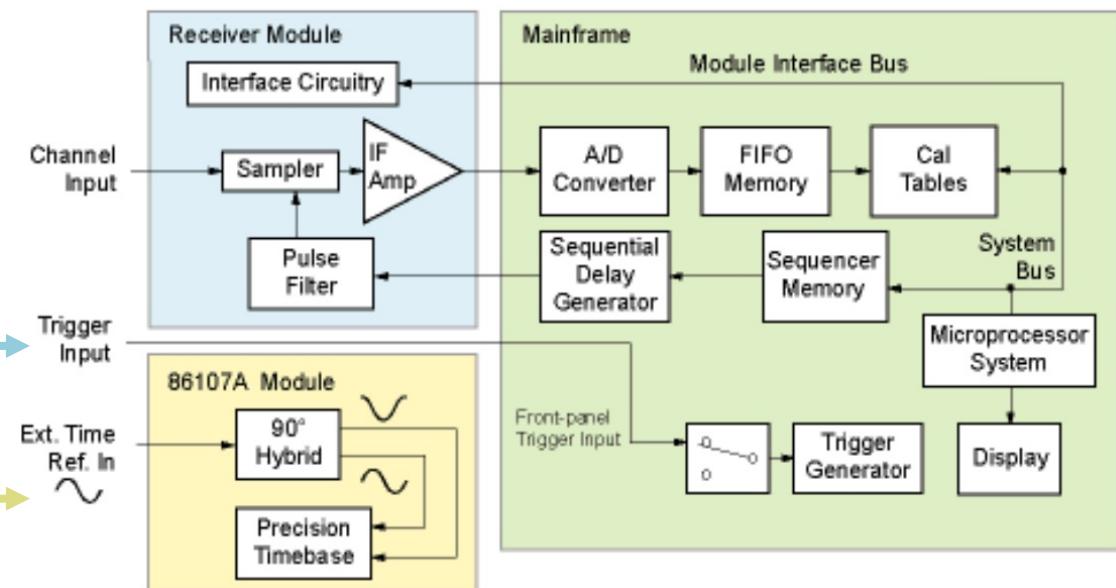
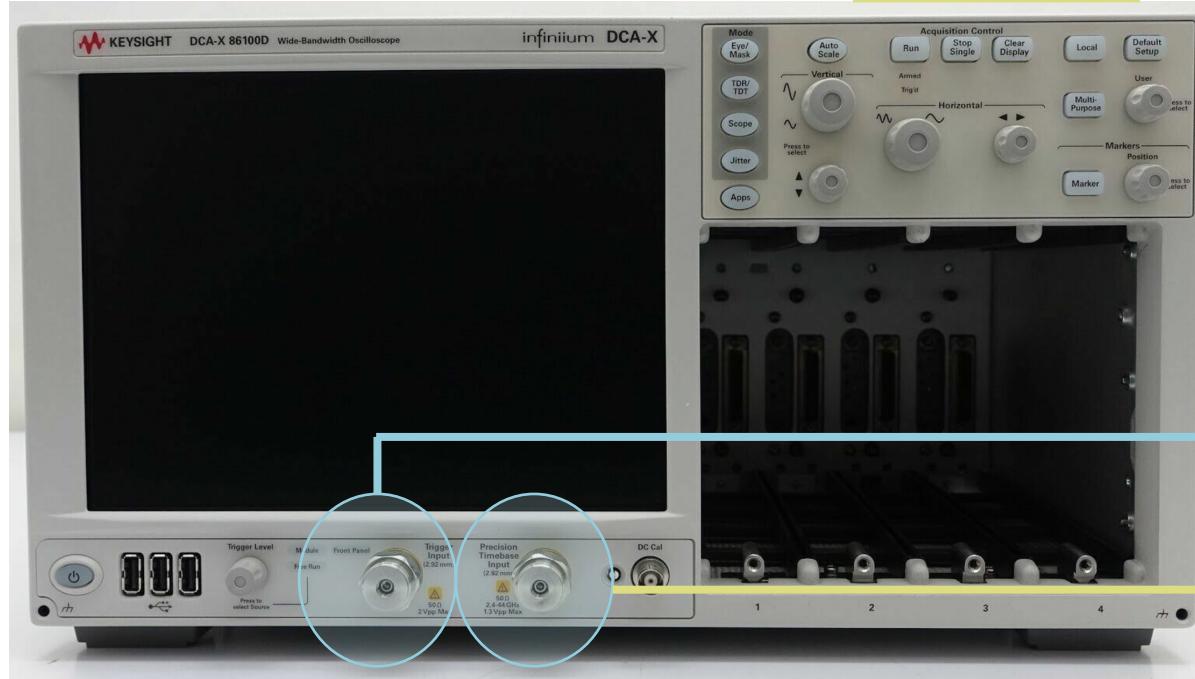
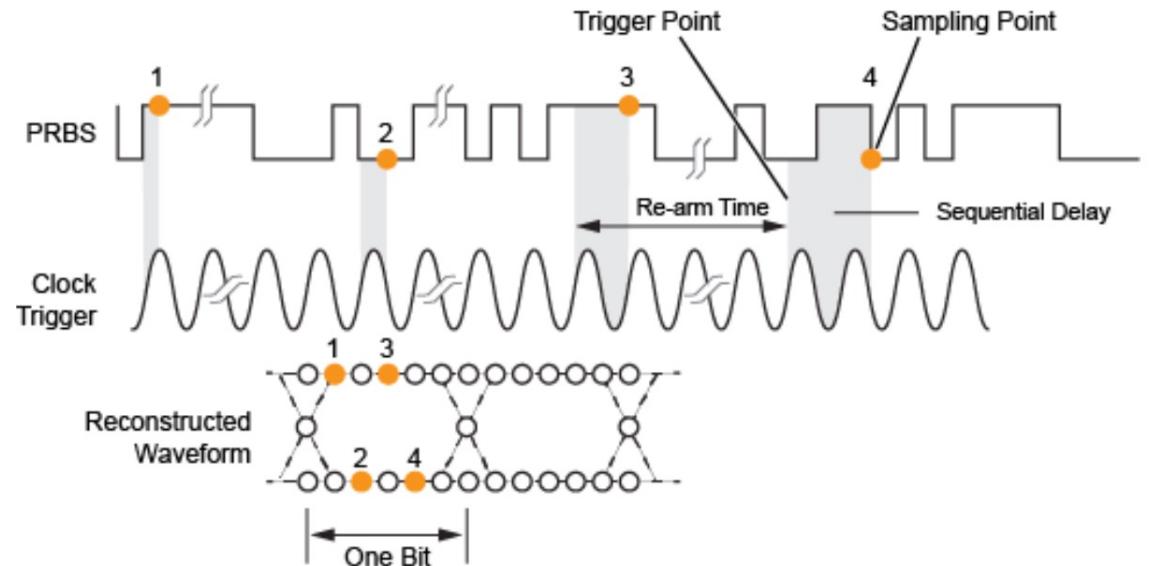


- My name went behind each photo while Shahriar was in rush for the preparation...
- Fortunately, this presentation includes more photos so... enjoy!!! :D

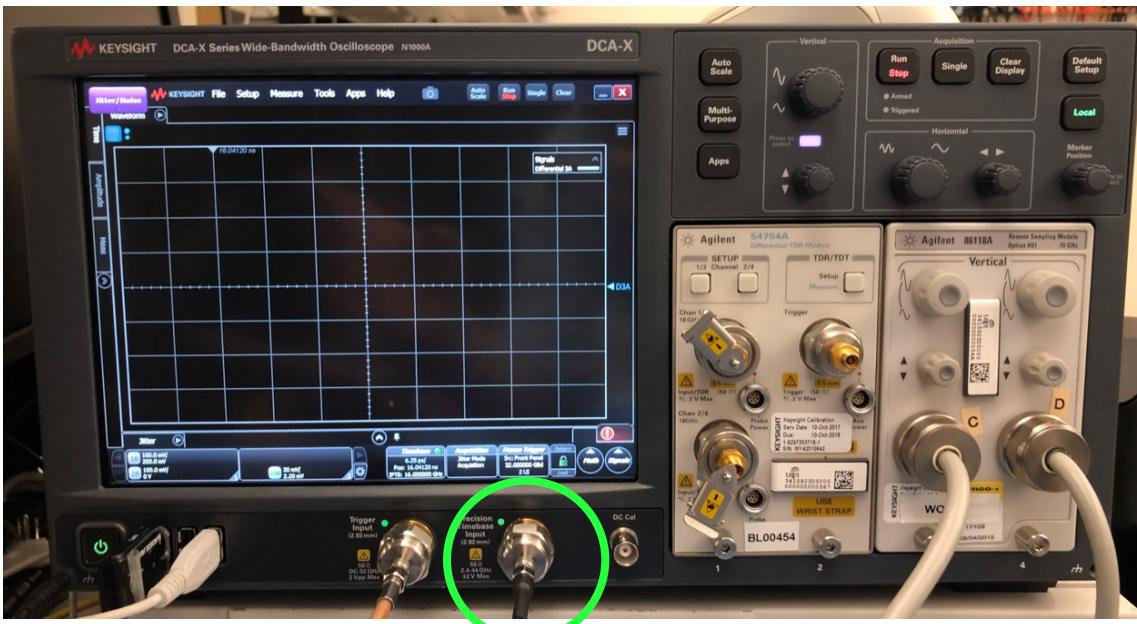
86118A Sampling Scope



Today's Topic

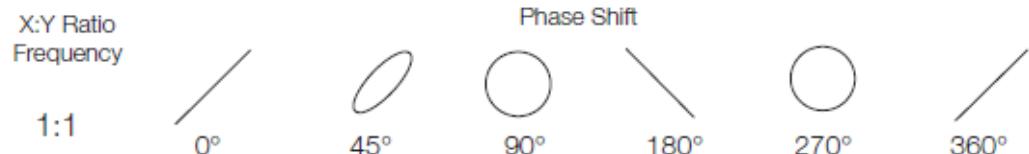
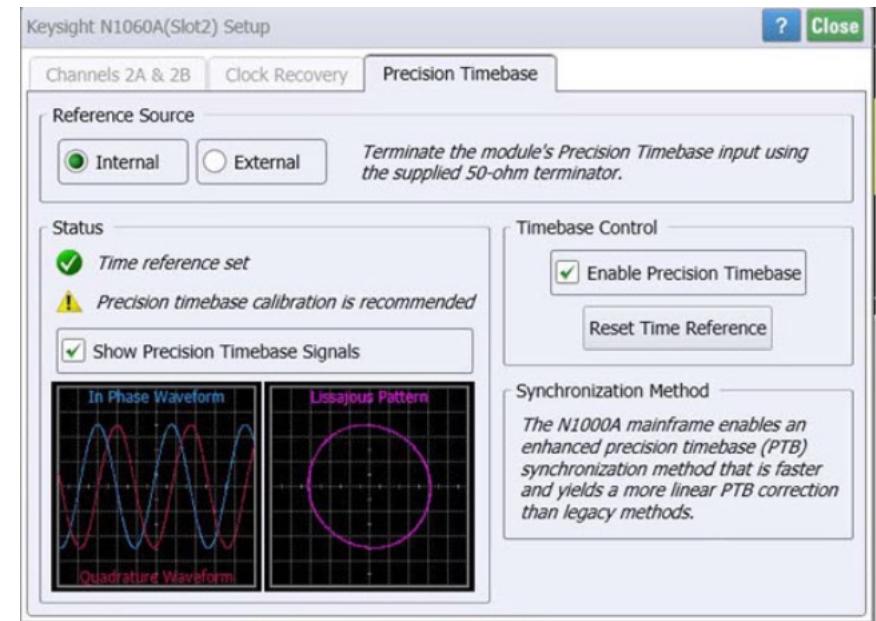


CHECK: signal integrity of the precision timebase (PTB) input



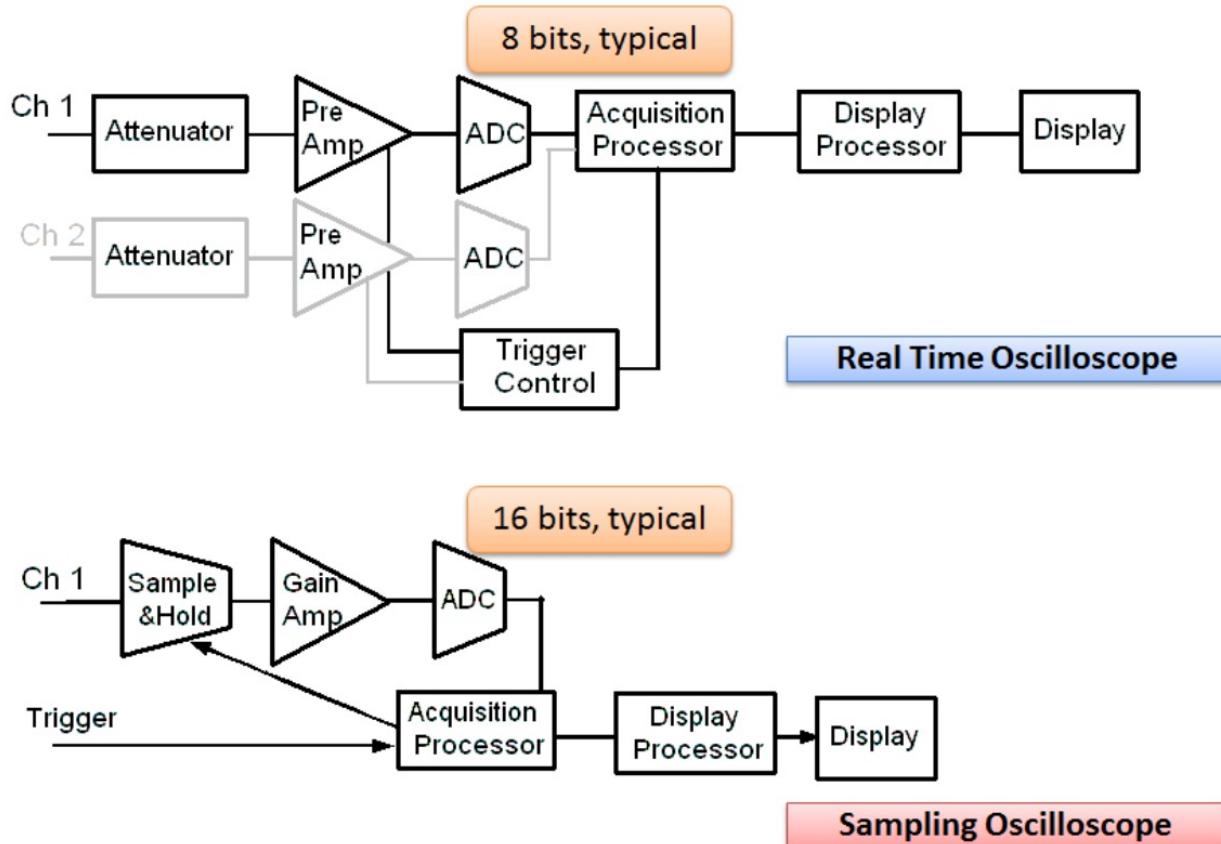
Why do we need quadrature signals for PTB?

- With a known period relationship and frequency, we can estimate the timebase errors.
- P. D. Hale *et al.*, “Compensation of random and systematic timing errors in sampling oscilloscopes,” IEEE Trans. Microw. Theory Tech., vol. 55, no. 6, pp. 2146– 2154, Dec. 2006.



- Lissajous pattern shows how good your PTB input is.
- If you see an elliptical shape, you need to either
 - calibrate your precision timebase input, or
 - check linearity of your input source
 - Optimal with sine-wave input

Real-Time Oscilloscope vs Equivalent-Time Sampling Scope



Sampling scope

Advantages:

- Extremely low noise floor
 - High ADC resolution -> low quantization noise
 - No front-end attenuator
- Cost effective design verification solution!
 - A lot cheaper than RT scope for the same BW

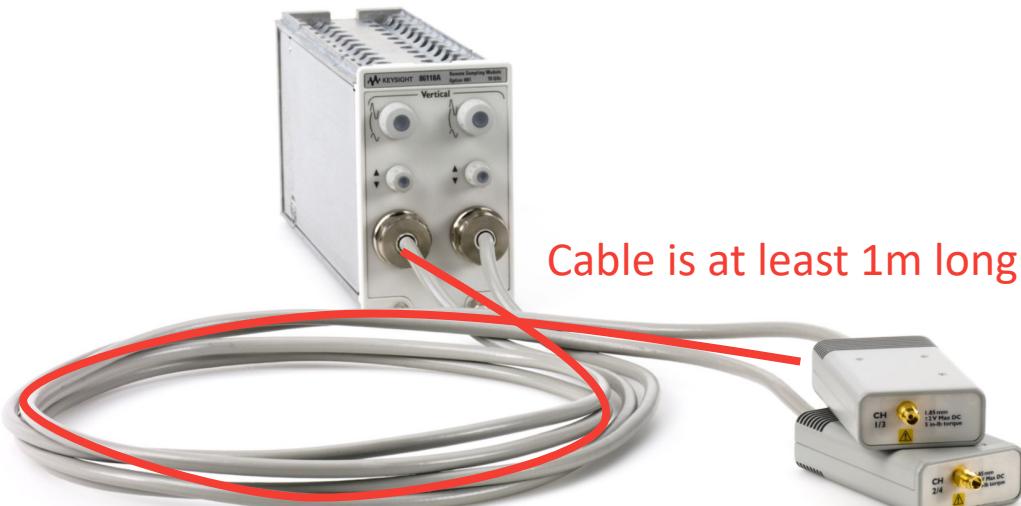
Disadvantages:

- repeating signal is recommended (e.g., PRBS pattern)
 - In modern design, sampling scope can take non-repeating signals with a clock-pattern trigger and limited functions (e.g., no pattern lock)
- Trigger (or Precision Time Base) is required!
 - If DUT does not provide coherent trigger signal, it needs to be paired with external CDR!

For debugging, use RT scope

For design verification, use sampling scope

Motivation



- BW goes up to 70 GHz. How?!
 - 0% chance to fit high-speed ADC inside the remote head module
- Watched ‘the signal path’ channel. Shahriar does not cover the details of the remote head
 - But showed that the mainframe has ADC.
 - <https://www.youtube.com/watch?v=M6Ho5loBjLo>
 - ***what is inside the remote-head module then?***
- I did lots of googling, paper/patent scavenging, asking random questions on EEVBlog, etc.
- Tektronix Circuit Concept book provided me lots of insights and information !

Remote Head – Teardown #1



There are two screws sitting behind the sticker.

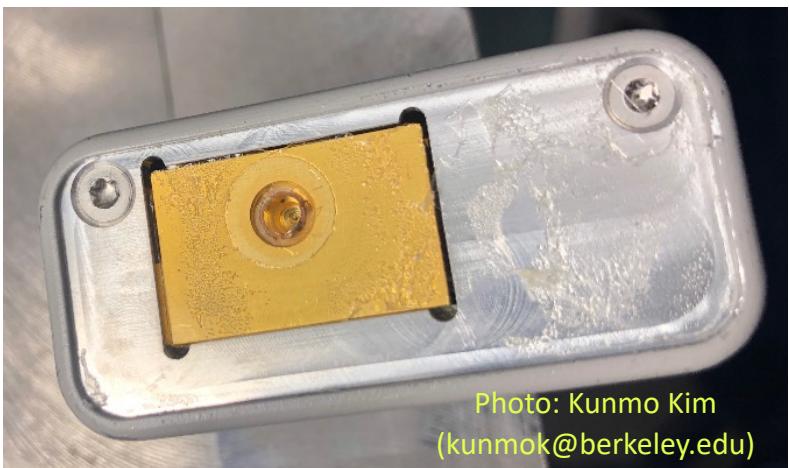
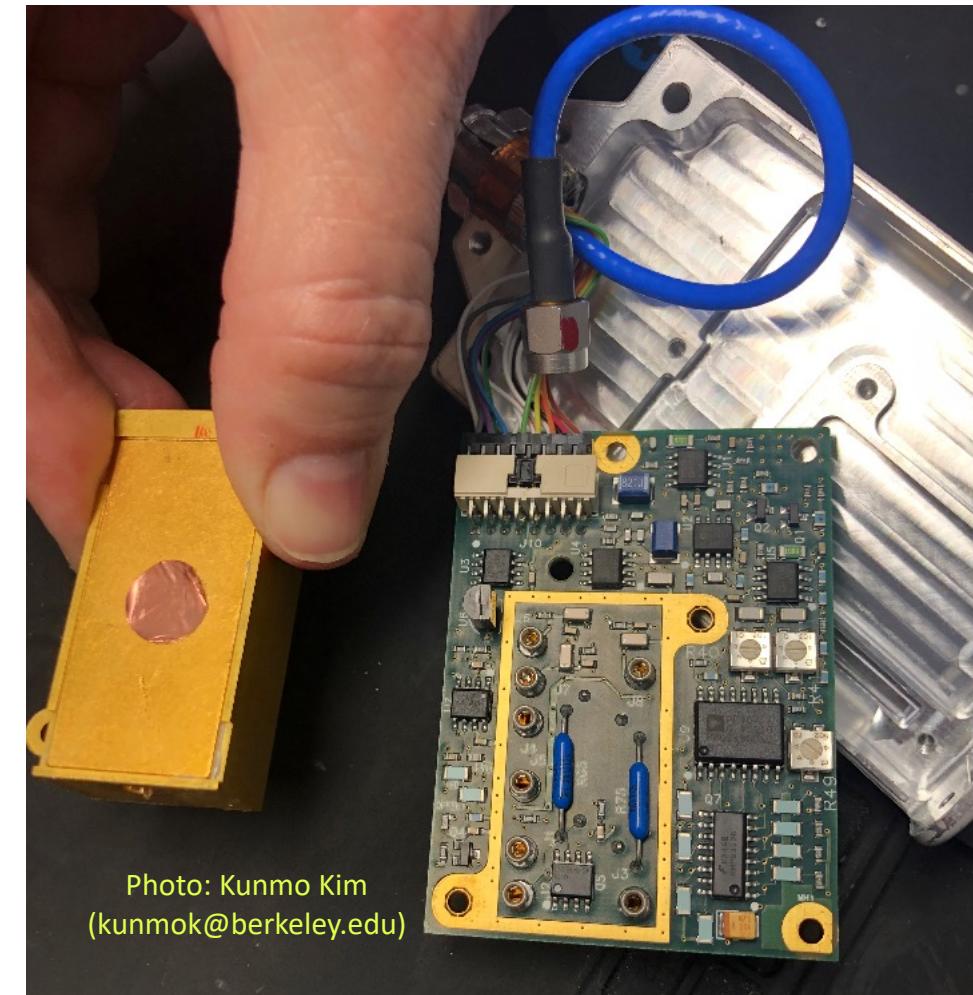
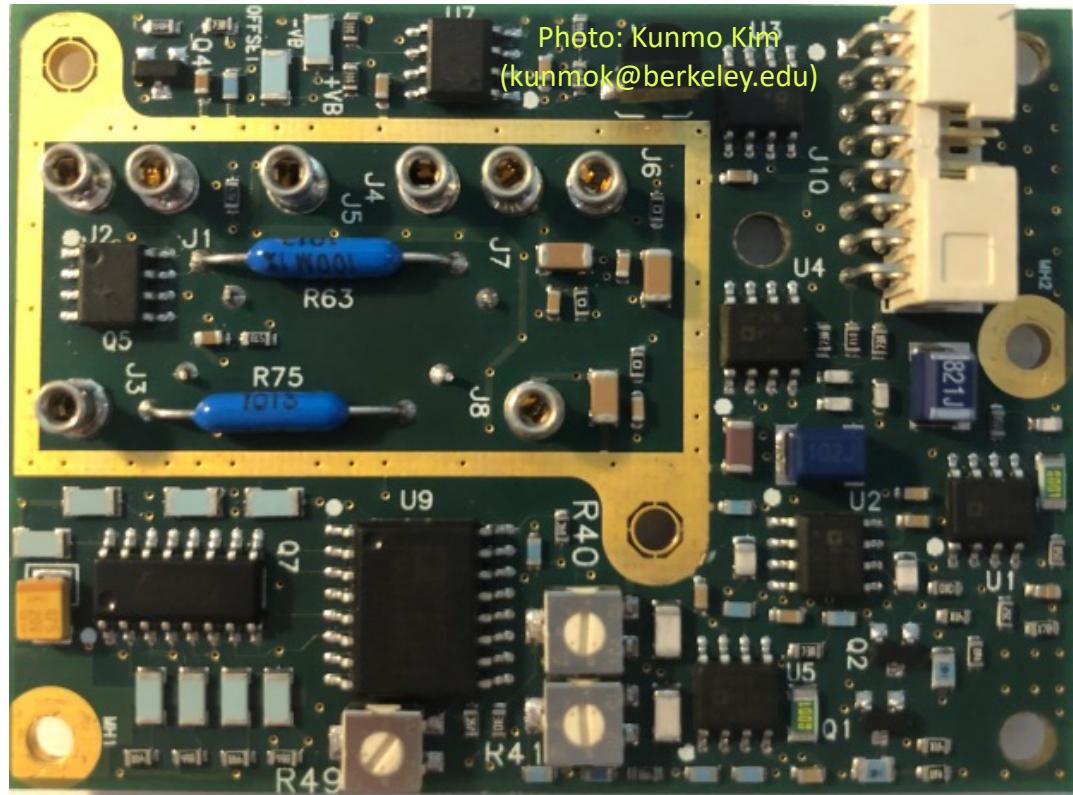


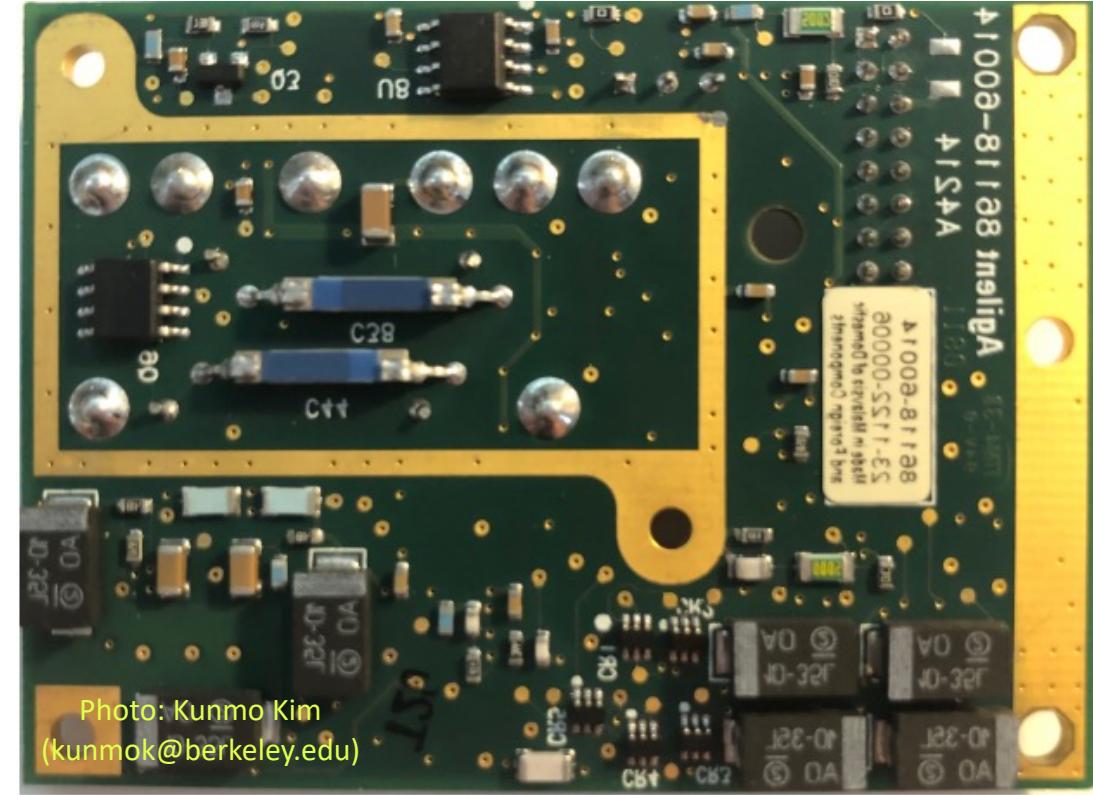
Photo: Kunmo Kim
(kunmok@berkeley.edu)



Remote Head – Teardown #2

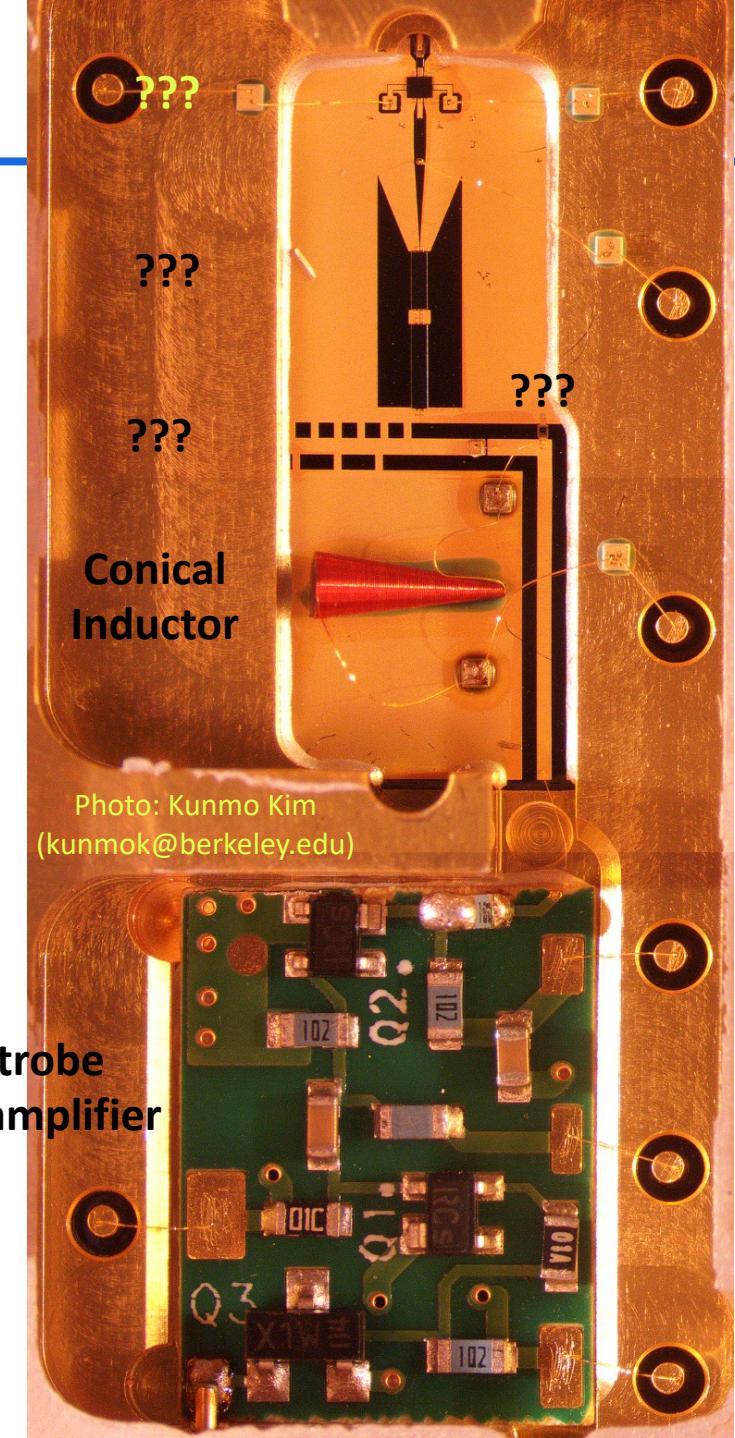


Front-Side



Back-Side

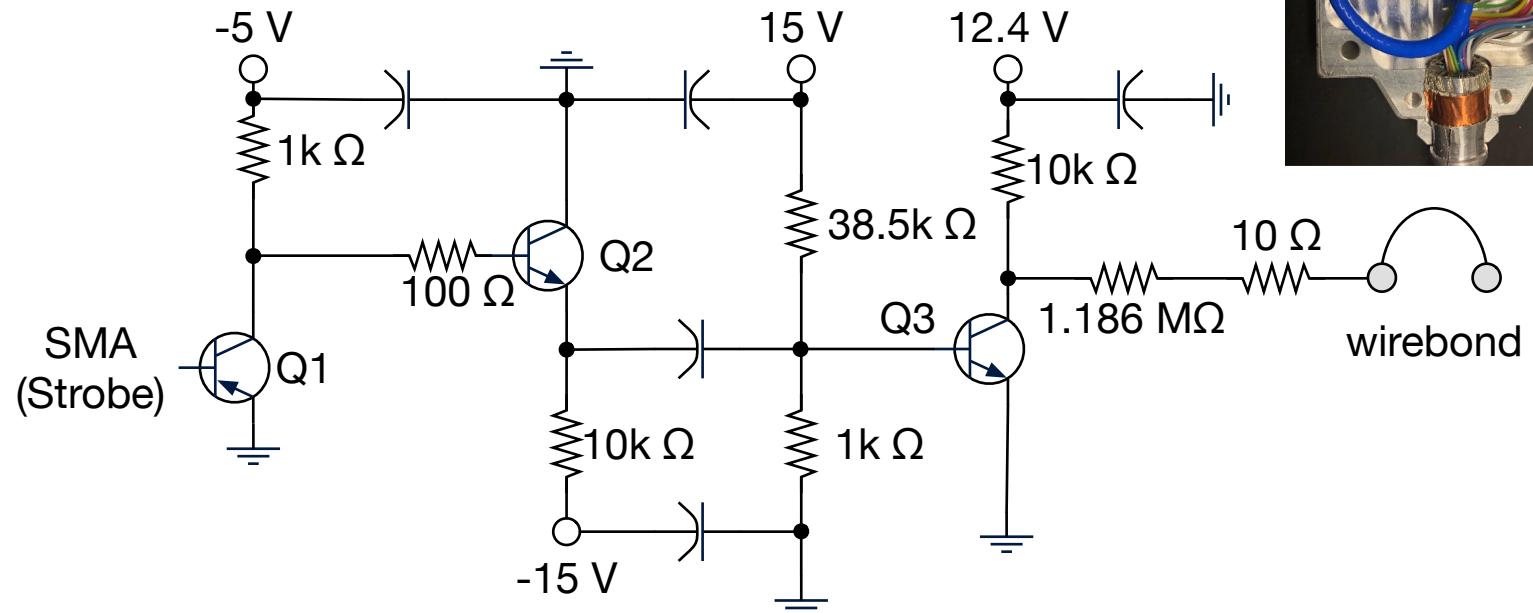
Remote Head – Teardown #3



Quiz: Each side of sampling gate is actually shorted to GND. Why? (explained later!)

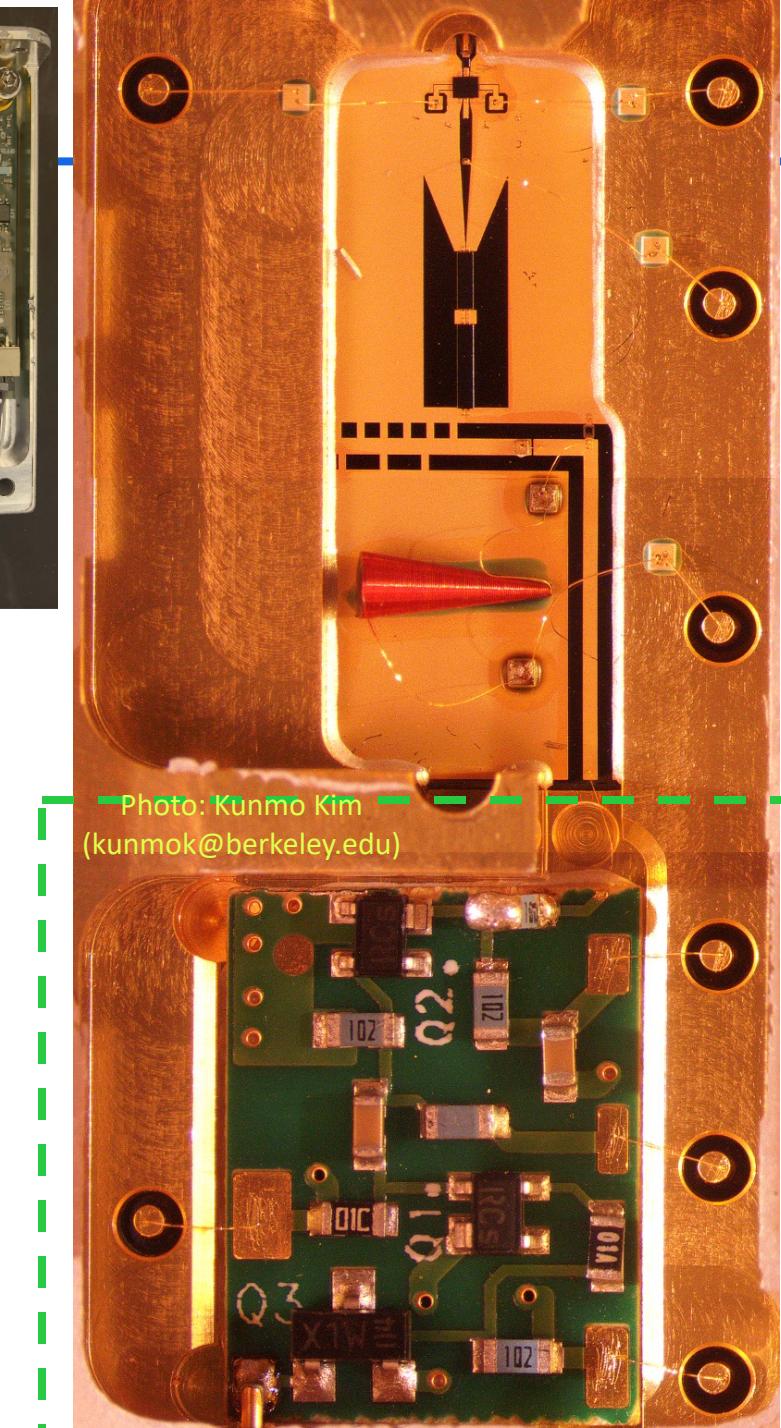
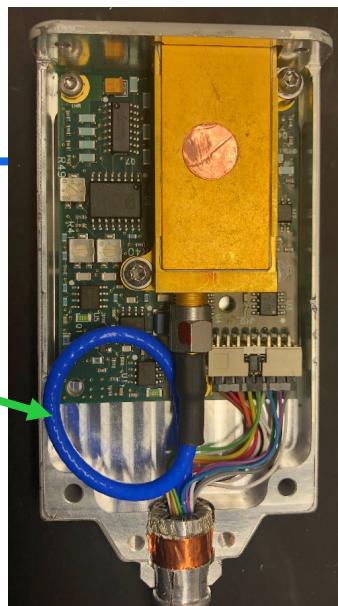
Strobe Preamplifier

Strobe preamplifier



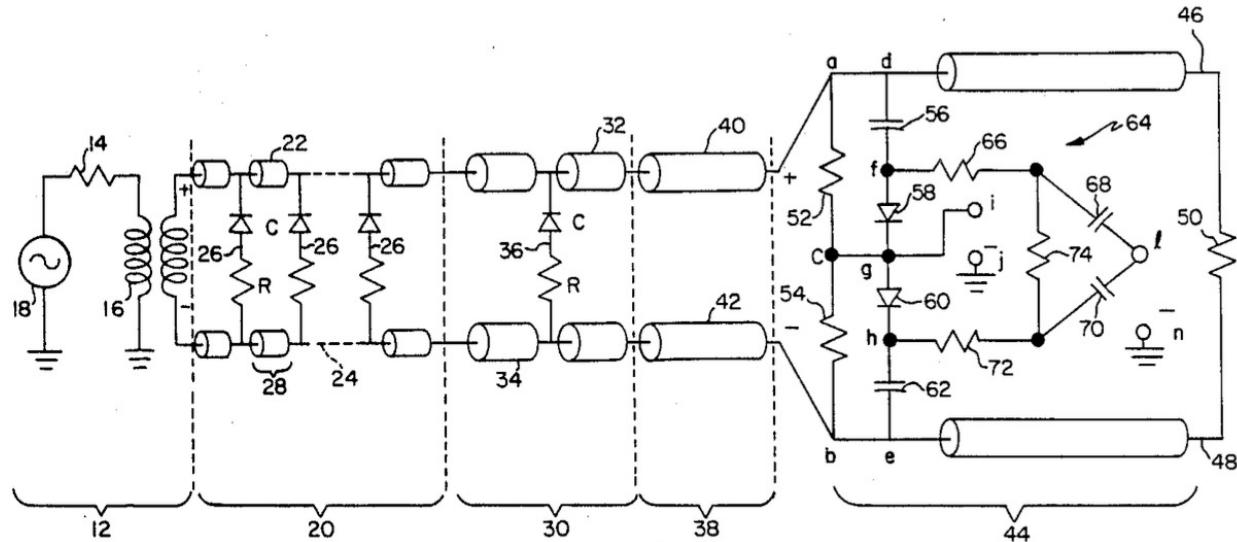
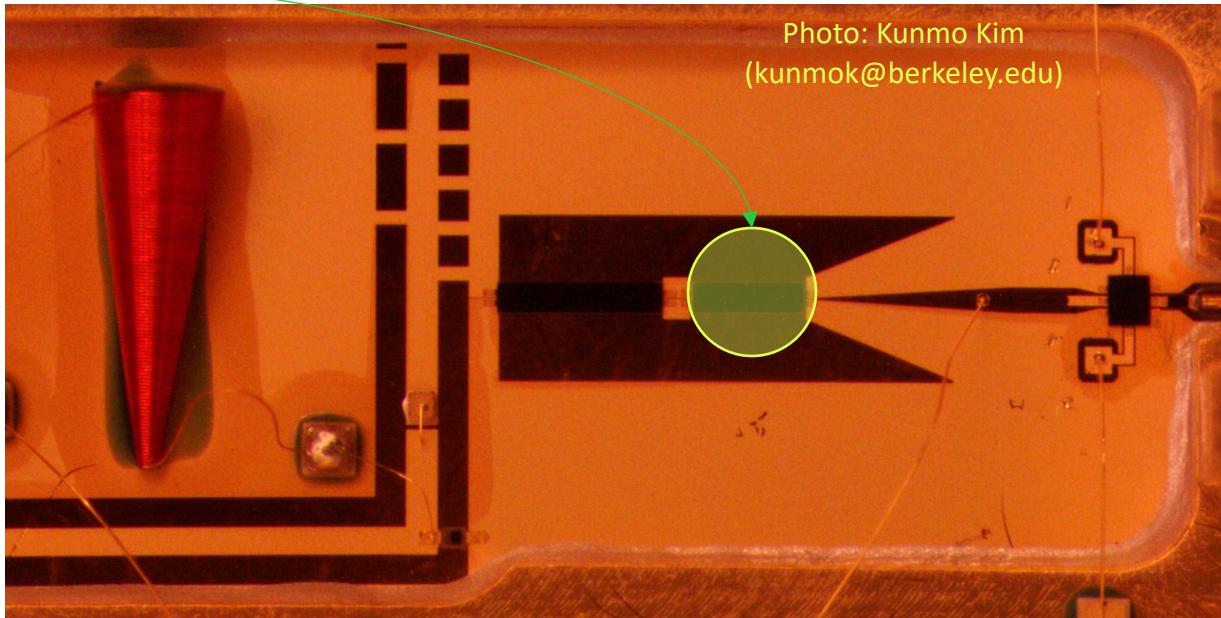
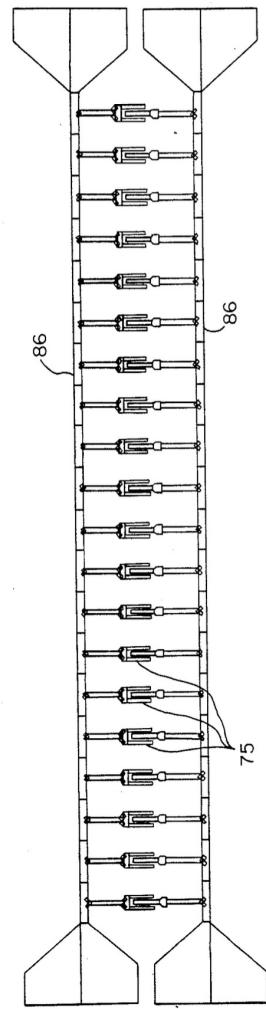
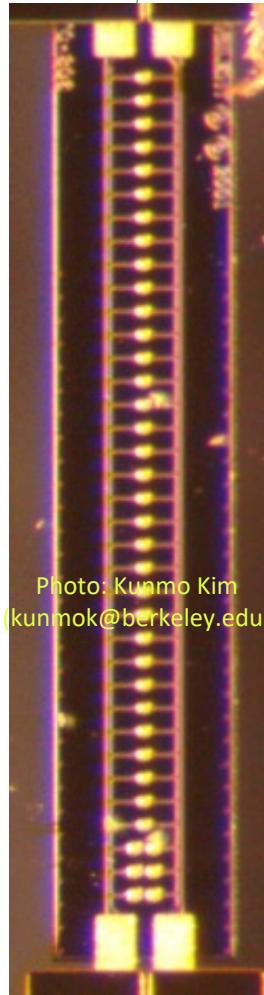
Q1 : BFT93
Q2 & Q3: BFP193W

Strobe input via coax cable.
Strobe signal is coming from
the mainframe.



After days of patent scavenge...

Pop Quiz: Each side of sampling gate is shorted to GND. Why?



Patent #: US4956568A

Non-Linear Transmission Line

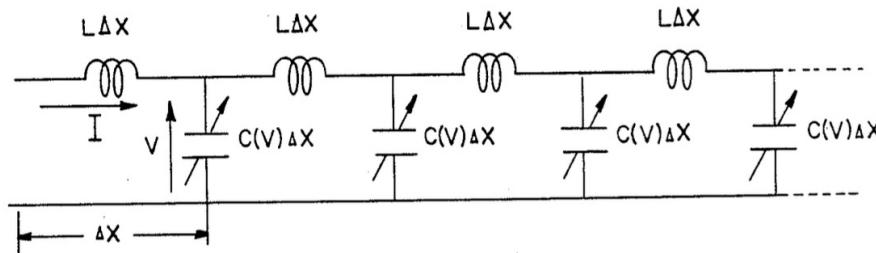


FIG.1

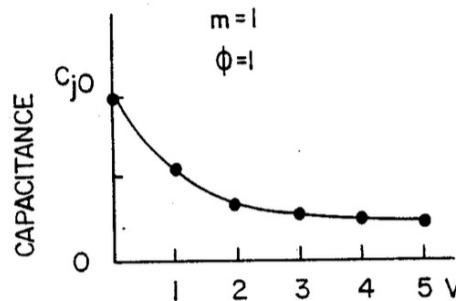


FIG.2

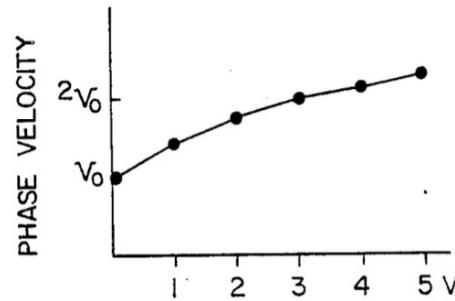


FIG.3

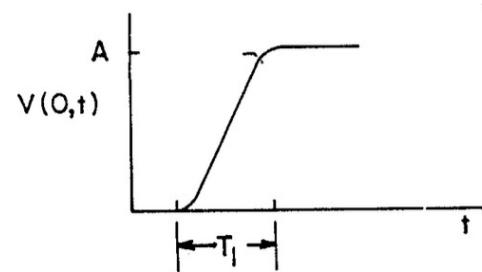


FIG.4

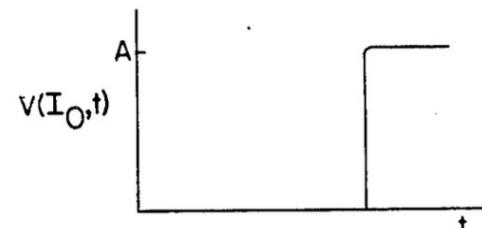
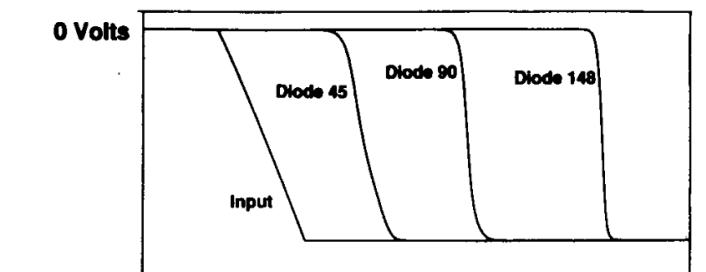
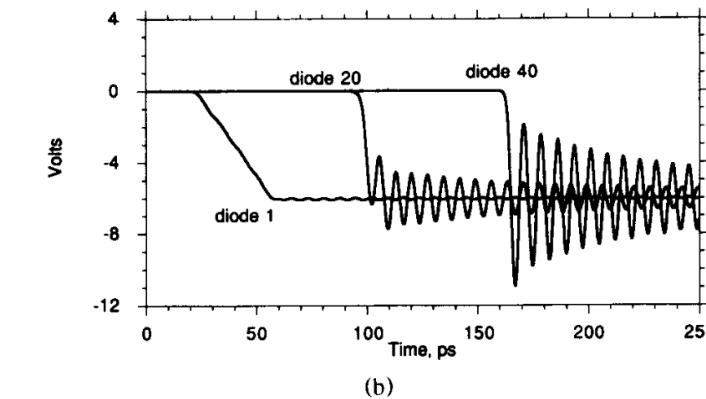


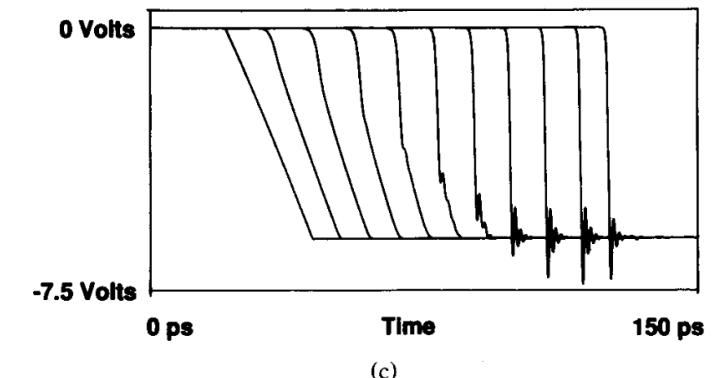
FIG.5



(a)



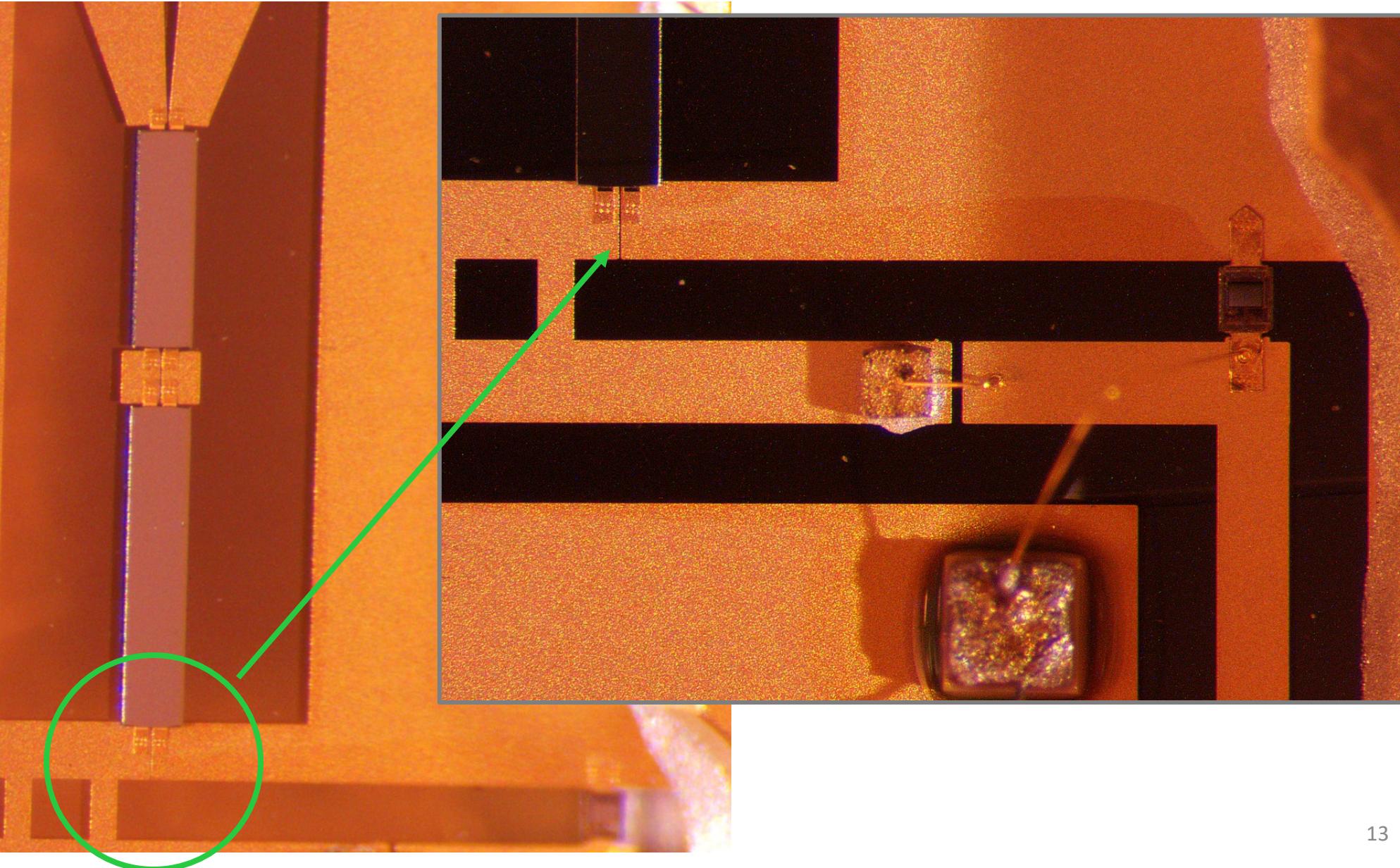
(b)



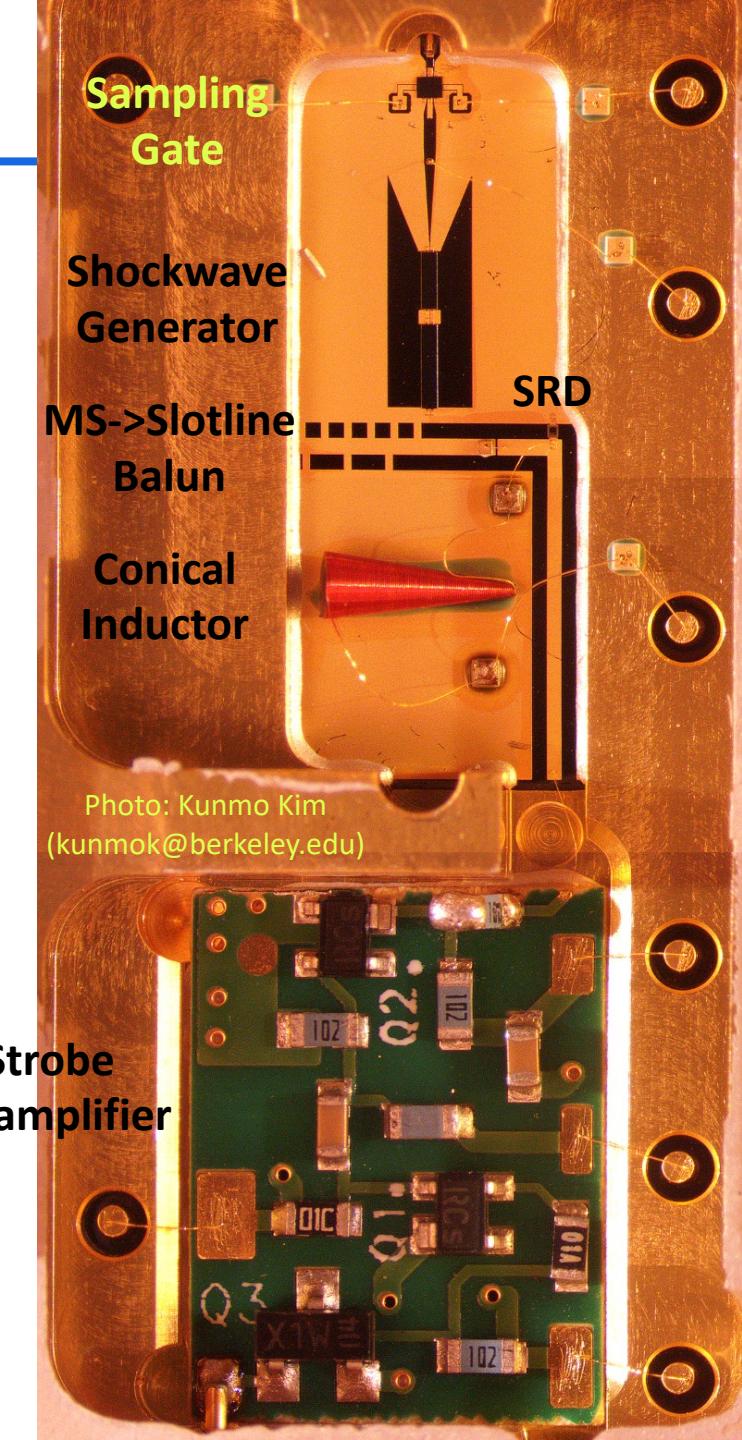
(c)

Slotline Balun

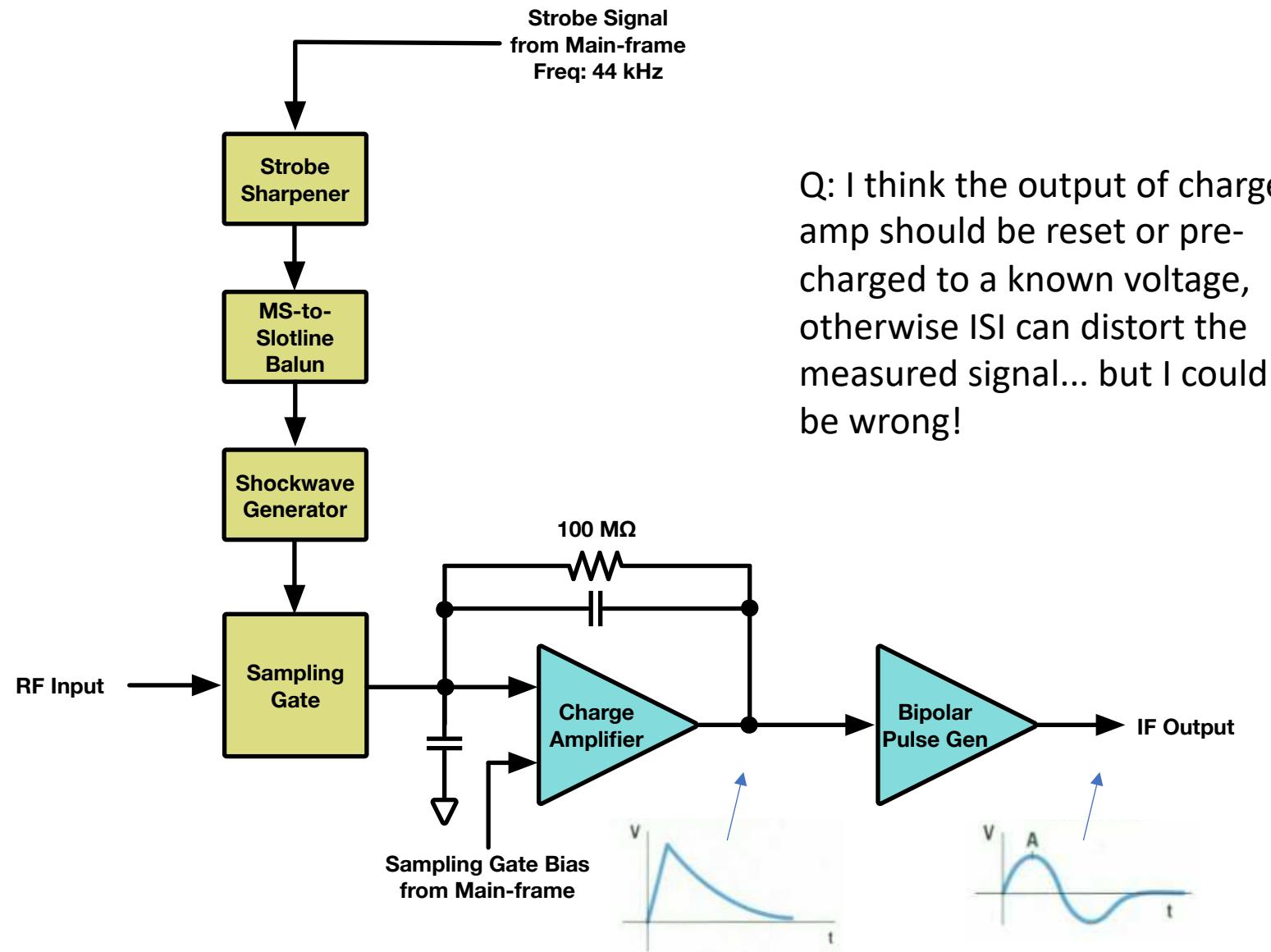
Photo: Kunmo Kim
(kunmok@berkeley.edu)



Remote Head – Revealed

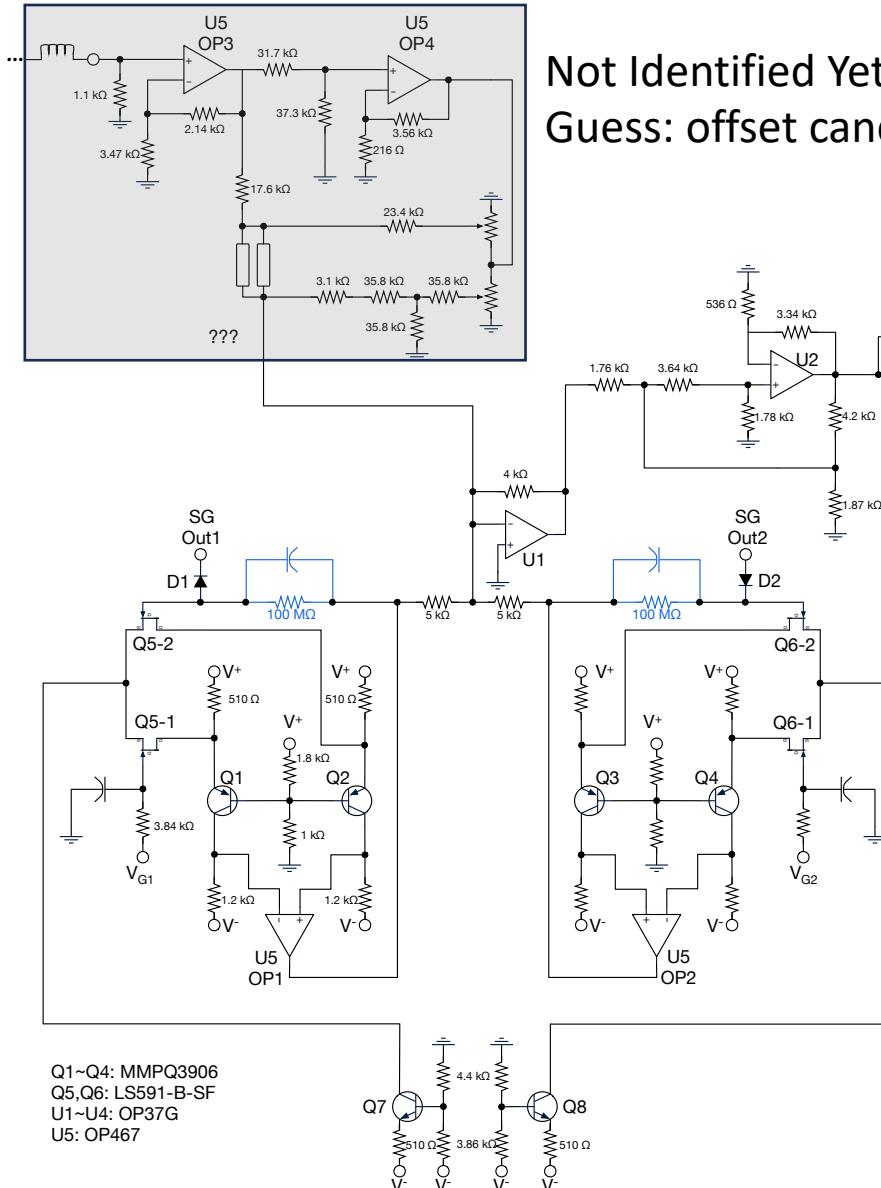


Remote Head – Teardown #4

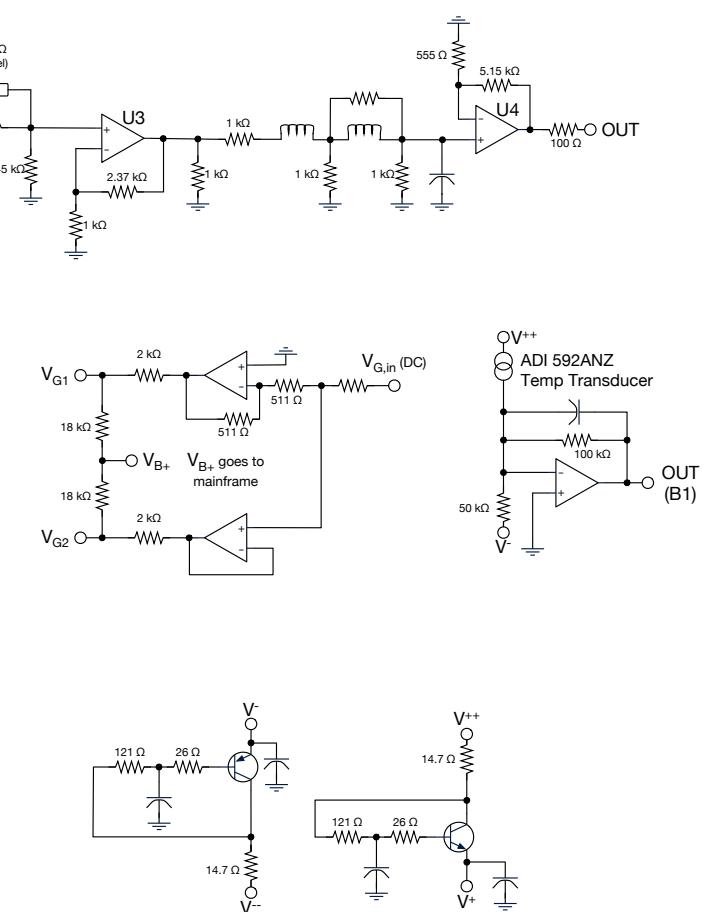


Q: I think the output of charge amp should be reset or pre-charged to a known voltage, otherwise ISI can distort the measured signal... but I could be wrong!

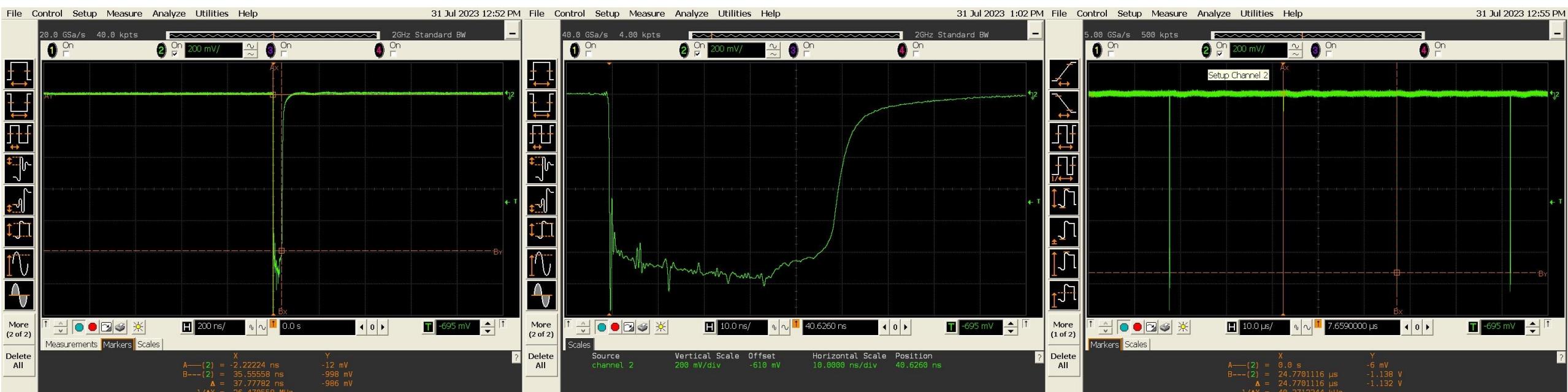
Remote Head – Teardown #5



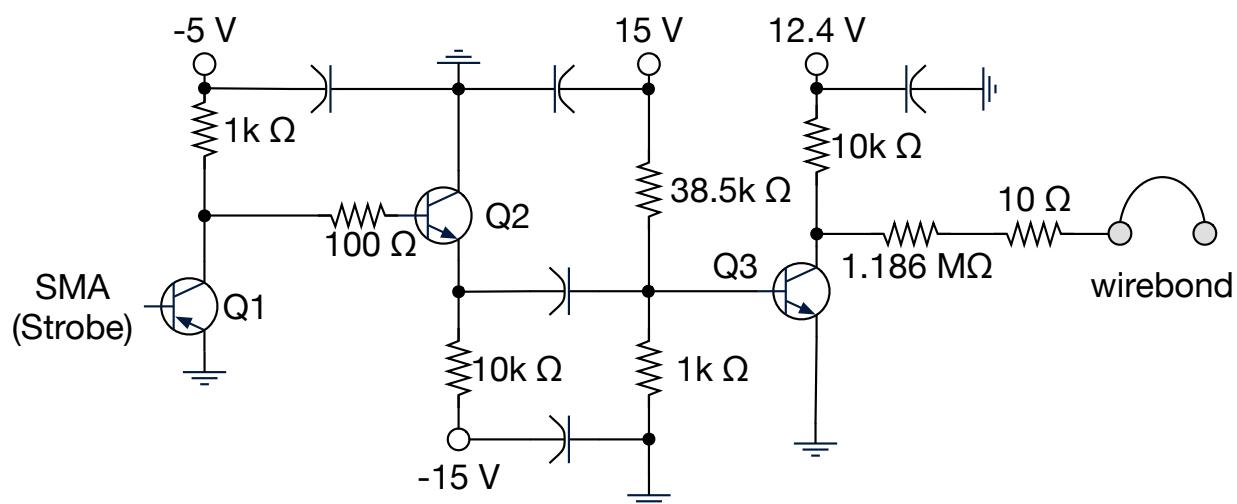
Not Identified Yet... Probably some connections missing
Guess: offset cancellation... but not sure 100%



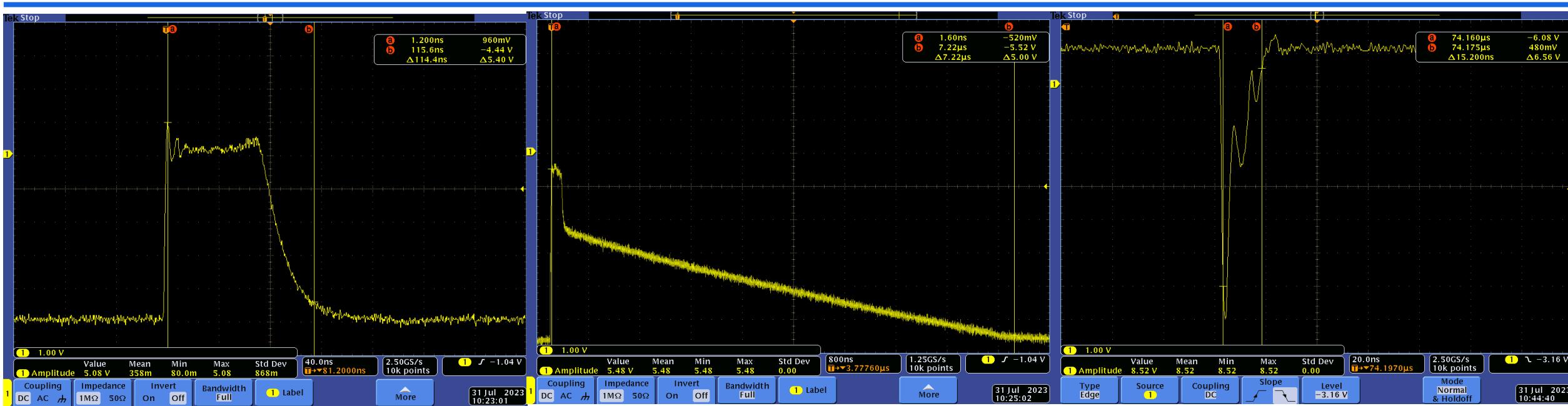
Input of Strobe Amplifier



Strobe preamplifier



Probed signal

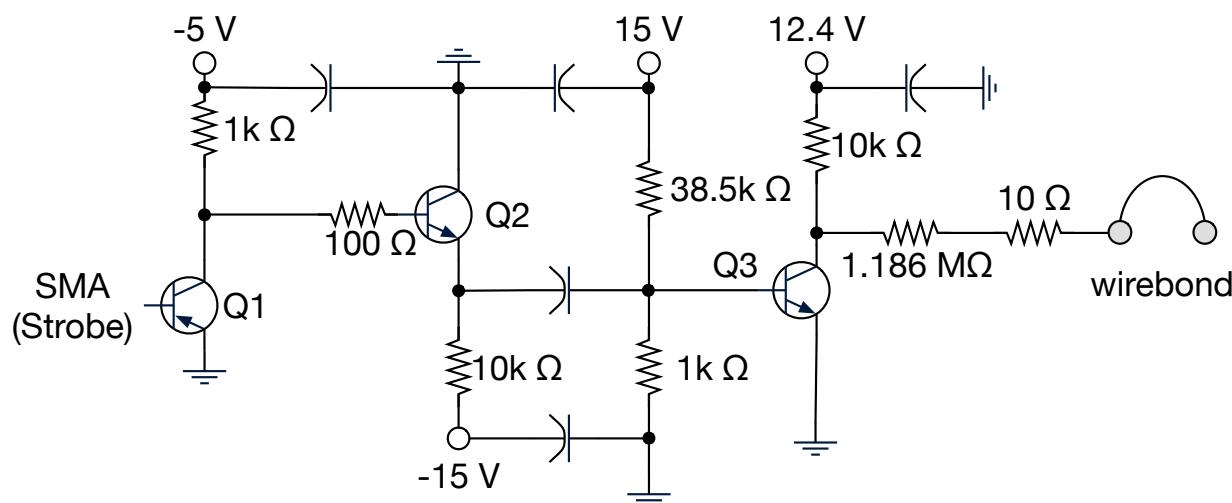


Q1 collector

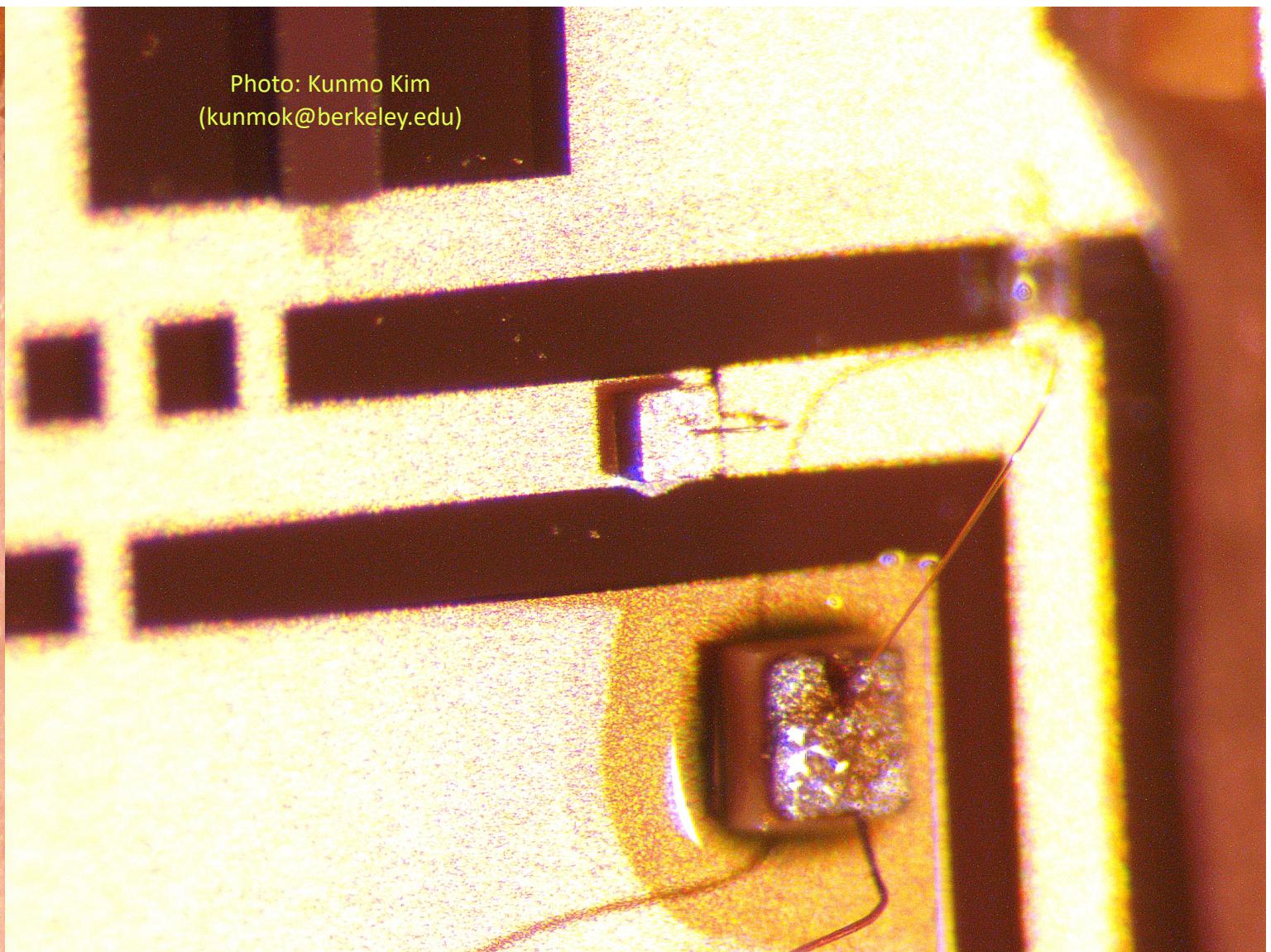
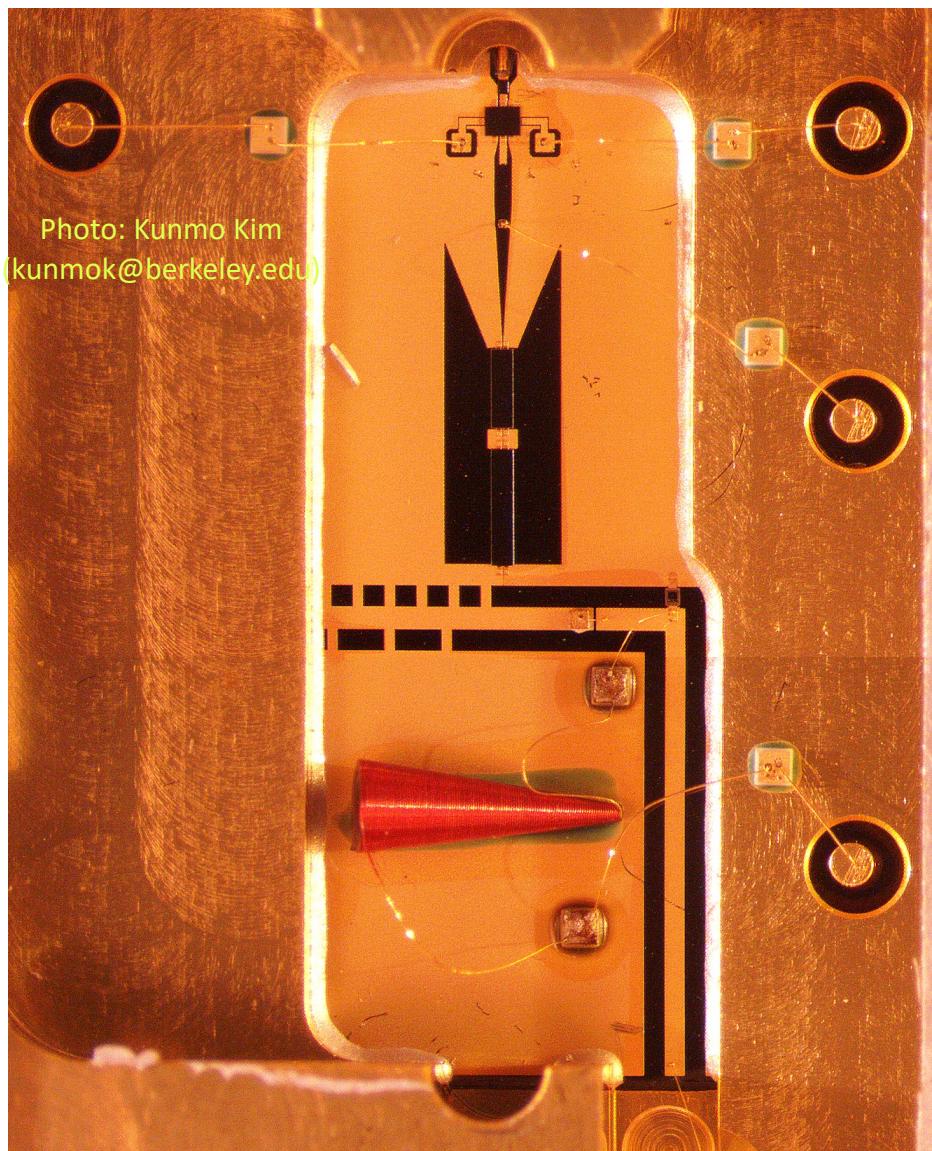
Strobe preamplifier

Q2 Emitter

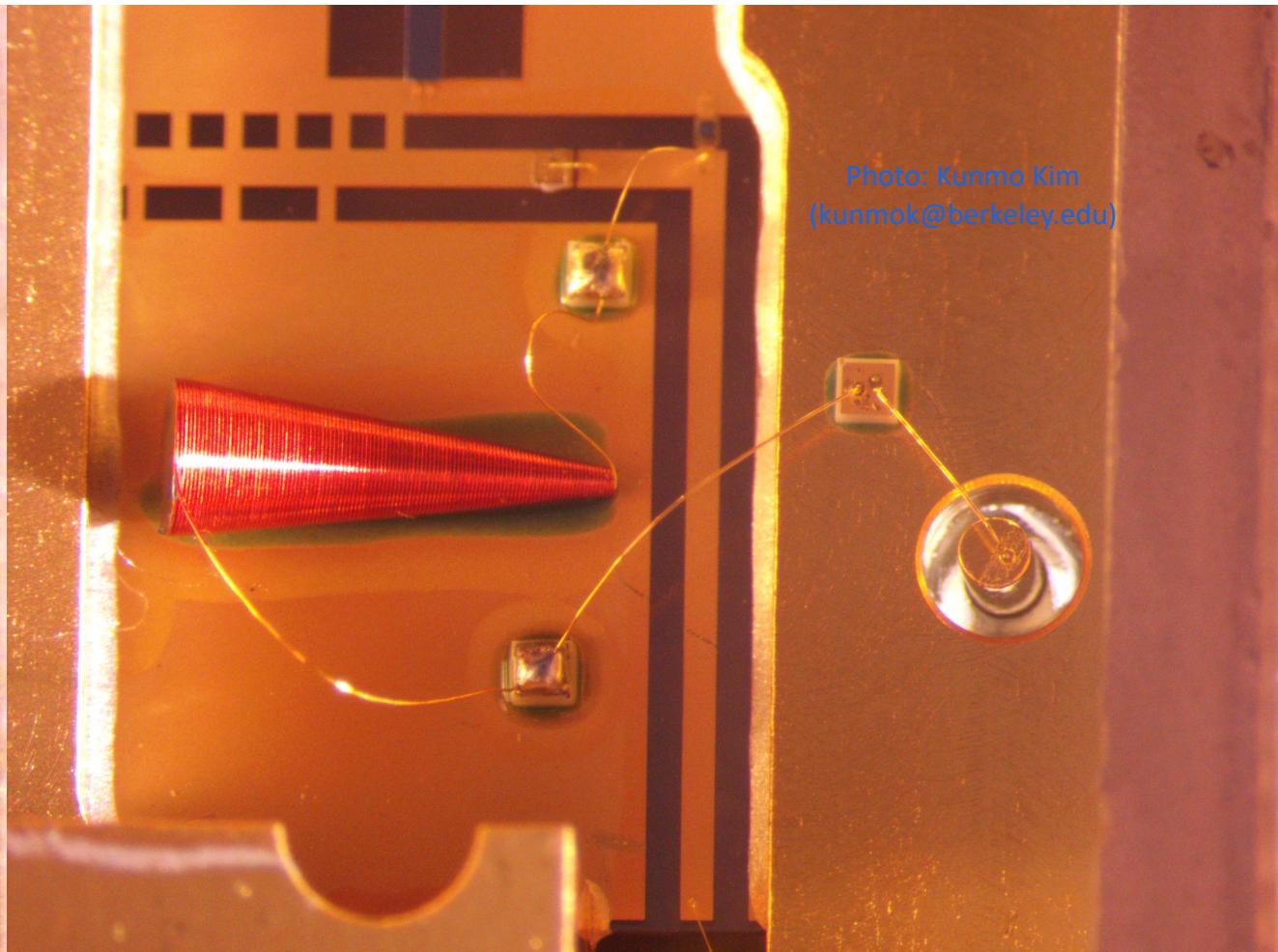
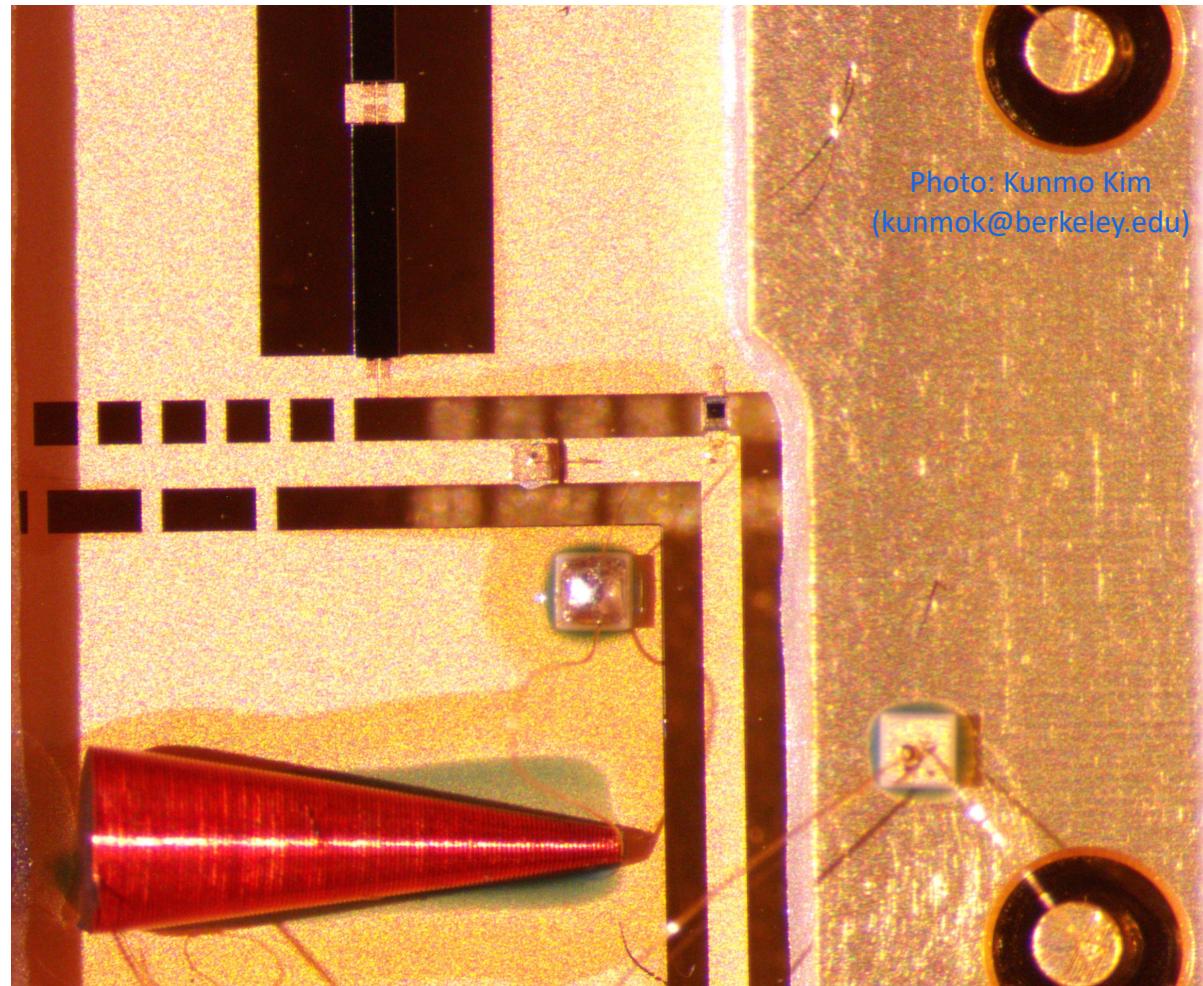
Q3 Collector



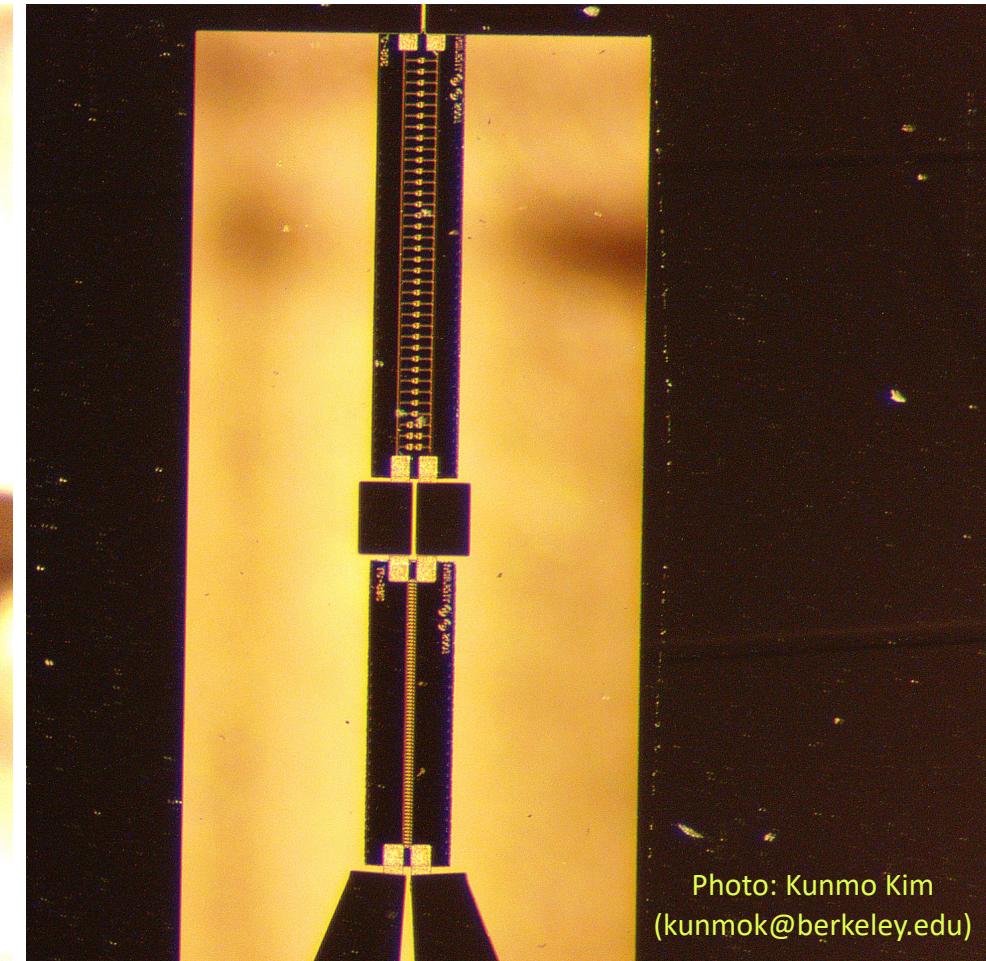
Other beautiful photos



Other beautiful photos

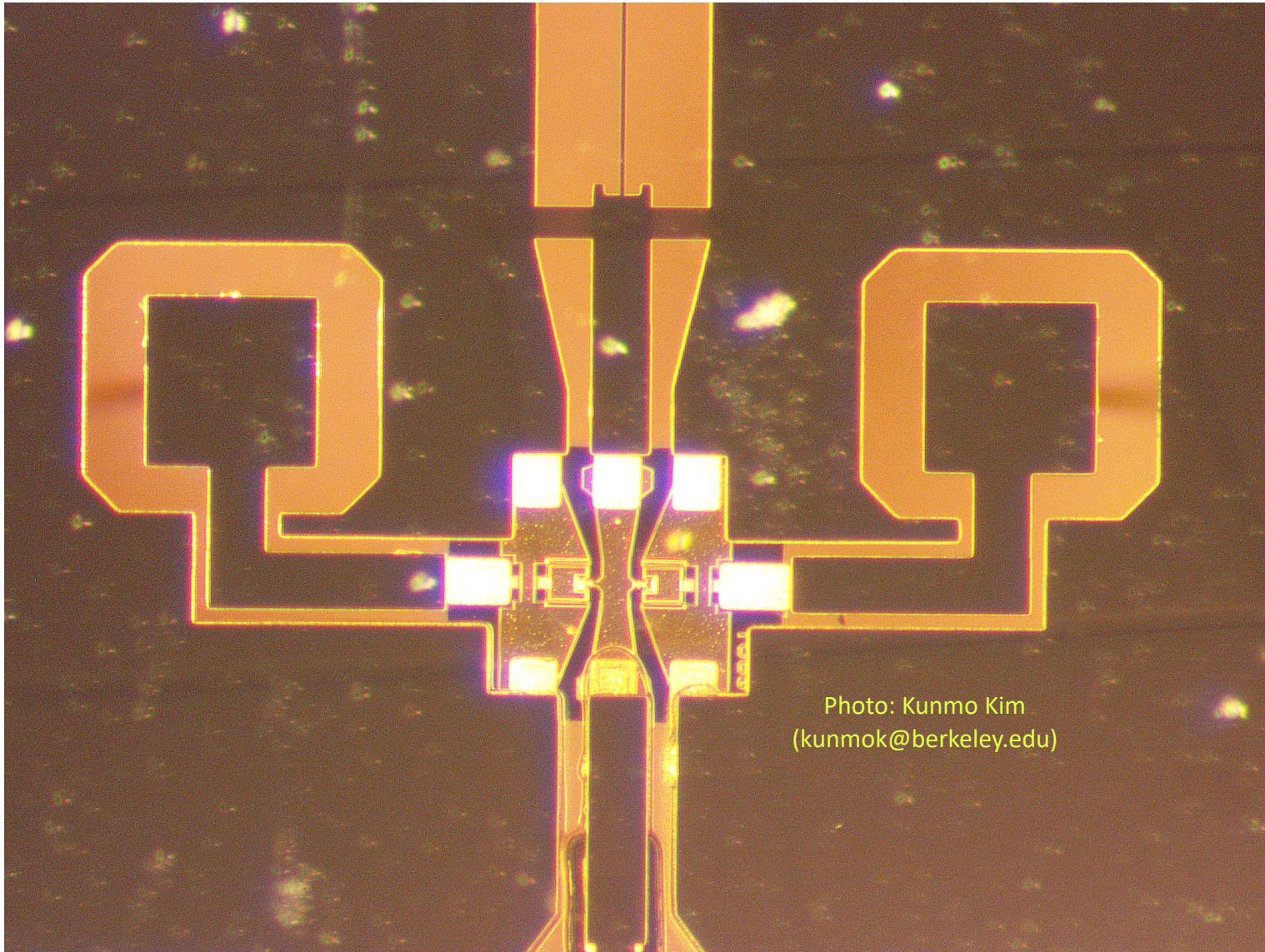


Other beautiful photos



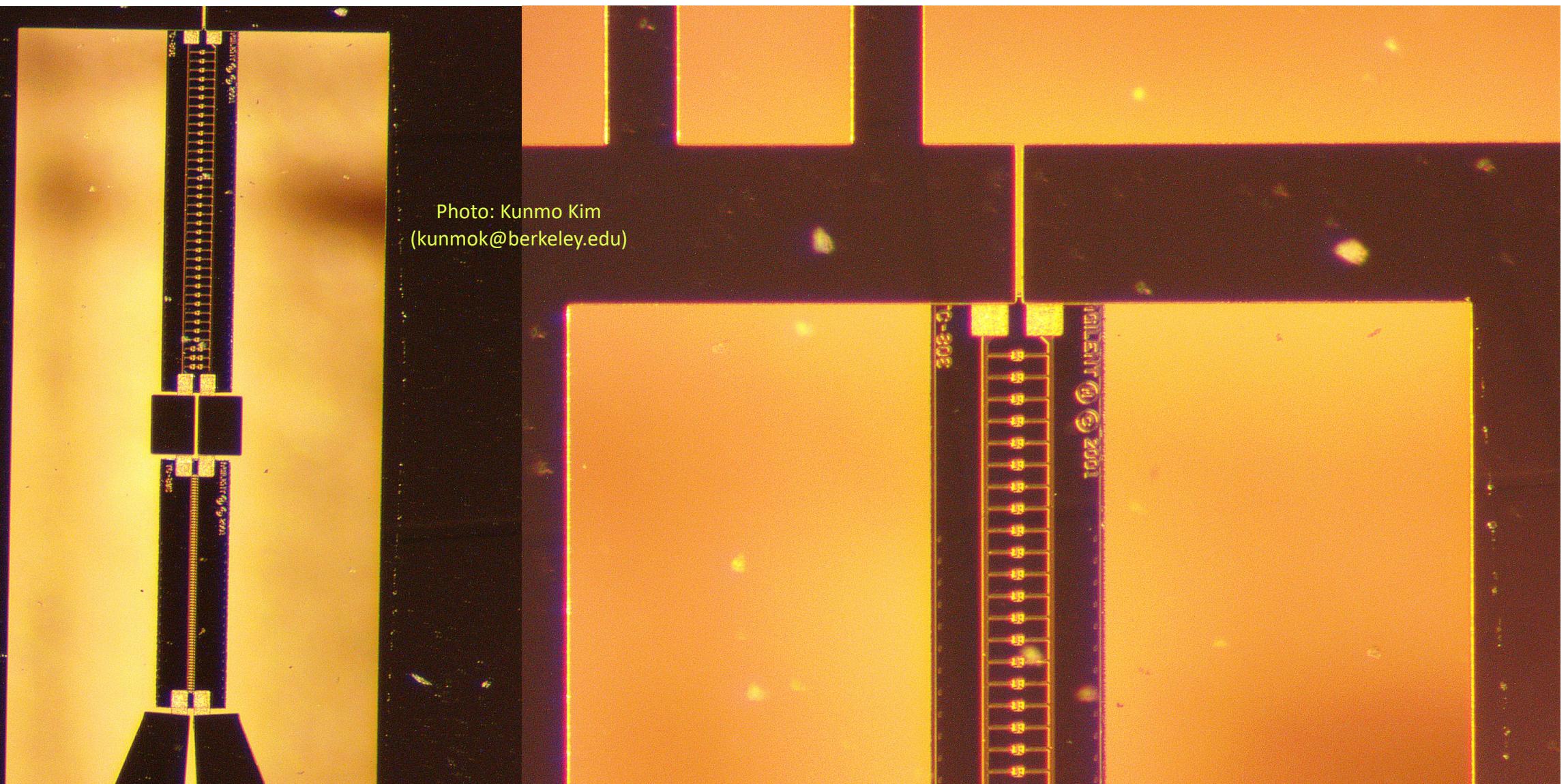
Backside of sampling gate + non-linear transmission line (back of glass substrate)

Other beautiful photos



zoomed-in sampling gate die photo

Other beautiful photos



zoomed-in non-linear transmission line

Related References + Learning Materials

- Tektronix' Circuit Concept Series: Sampling Oscilloscope Circuits
- HP Journals
 - 1971 Nov.
 - 1973 Apr.
 - 1978 May.
 - 1986 Feb.
 - 1992 Oct.
 - 1996 Dec.
- P. D. Hale, C. M. Wang, D. F. Williams, K. A. Remley and J. D. Wepman, "Compensation of Random and Systematic Timing Errors in Sampling Oscilloscopes," in IEEE Transactions on Instrumentation and Measurement, vol. 55, no. 6, pp. 2146-2154, Dec. 2006.
- M. Kahrs, "50 years of RF and Microwave sampling," in IEEE Transactions on Microwave Theory and Techniques, vol. 51, no. 6, pages 1787-1805, June 2003.