Development of a low noise high frame rate CCD for adaptive optics

B. Martin Levine, James R. Janesick

Jet Propulsion Laboratory

California Institute of Technology

Pasadena, CA 91109

J. Christopher Shelton

Mt. Wilson Institute

Pasadena, CA 91106

Adaptive optics CCD

Overview:

- AO CCD rationale and design goals
- Fabrication and packaging
- Performance

  uniformity of response

  noise level

    noise reduction
- Planned improvements

  design improvements

  incorporation of new readout structures

Adaptive optics CCD

Rationale for CCD device:

- AO performance is limited by wavefront sensor sensitivity
- Integrated detector array more reliable than discrete element detectors
- Dector array is easier to scale to larger number of actuators

CCD applications:

- wavefront sensing

  tip/tilt

  higher order
- (fast) tracking

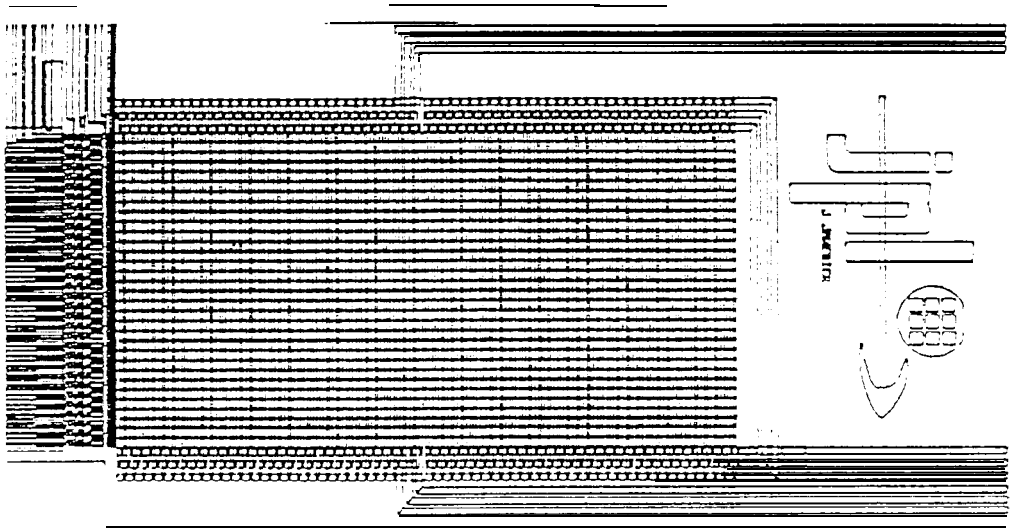
Adaptive optics CCD

Design goals for a high frame rate, low noise CCD detector:

Attribute	Quantity
Format	32(H) x 64(V) frame transfer silicon CCD
output ports	32 Skipper floating gate amplifiers located at the end of each signal column
Pixel size	30μm nominal
Read noise	1.5 electron rms noise floor
Frame rate	1.500 Hz
Quantum efficiency	60% rein, 8070 goal at 0.6-0.7 μm; 50% rein, 70% goal at 0.S μm
Maximum signal	4.000 electrons rnin, 10.000 electrons goal.
Frame transfer time	Transfer time/exposure time: 3% max, 1% goal. (900 ns/line max, 300 ns/line goal)
Dark current	1 electron/25ms per pixel at operating temperature (40 electrons/see per pixel)
Operating temperature	Room temperature goal. Packaging and electronics should permit cooling if needed.
Clocking	Will allow column pixel binning and fast clocking out of columns without readout. Design will allow for unidirectional/bidirectional frame transfer
Uniformity	All pixels should meet design goals listed above.

Adaptive optics CCD

Design of 32 x 64 CCD with Skipper amplifiers for each column:

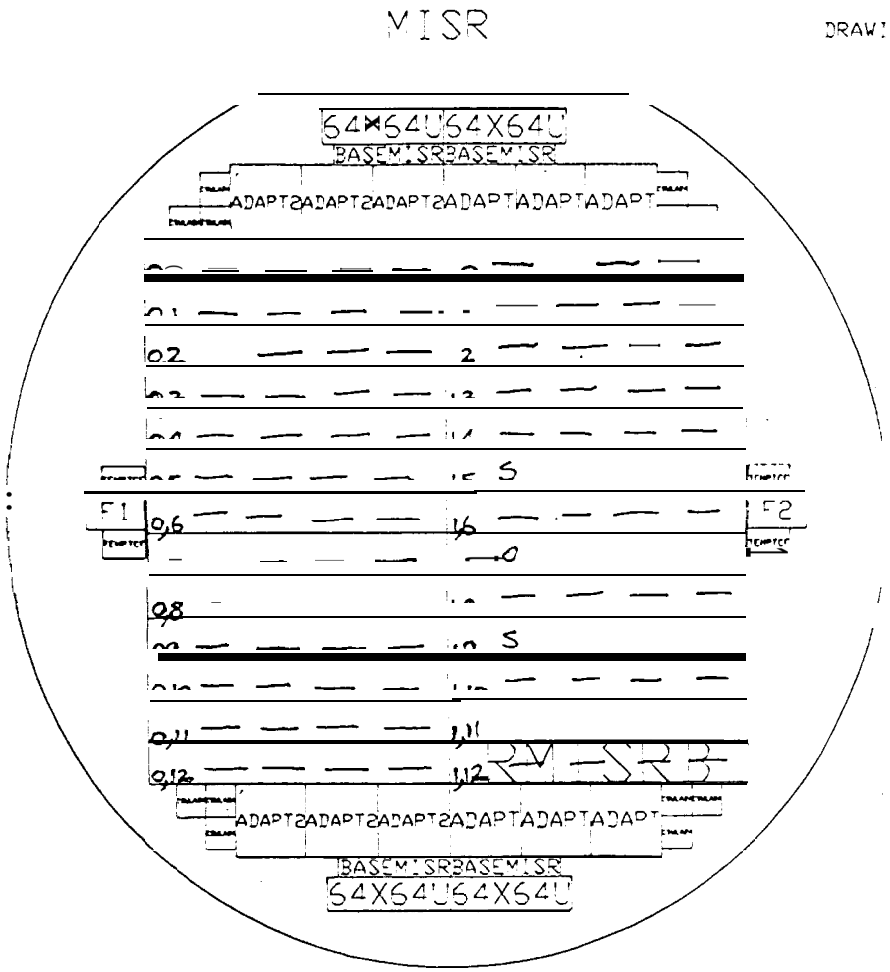


- **Parallel low** bandwidth readouts **allow** high frame rate

Adaptive optics CCD

Fabrication:

- 'Test' device on MISR fabrication
- Development lot plus two flight ots



DRAWING ID	FILE NAME	X DIM	Y DIM
F1	FAV600AB	6620.00	3840.00
F2	FAV600AR	6620.00	3840.00
TEMPTCF	TEMPTCF	4740.00	3040.00
ADAPT	ADAPT	8100.00	8100.00
ADAPT2	ADAPT2	8100.00	8100.00
BASEMISR	BASEMISR	12550.00	2200.00
CSULA2A	CSULA2A	13348.00	3619.00
RMISRB	RMISRB	34005.00	4577.00
TMISR21	TMISR21	34005.00	4577.00
BMISR21	BMISR21	34005.00	4577.00
64X64U	64X64U	13861.00	3687.00

LOT 1

WAFFER 12

James Janesick
NOV 18, 1992

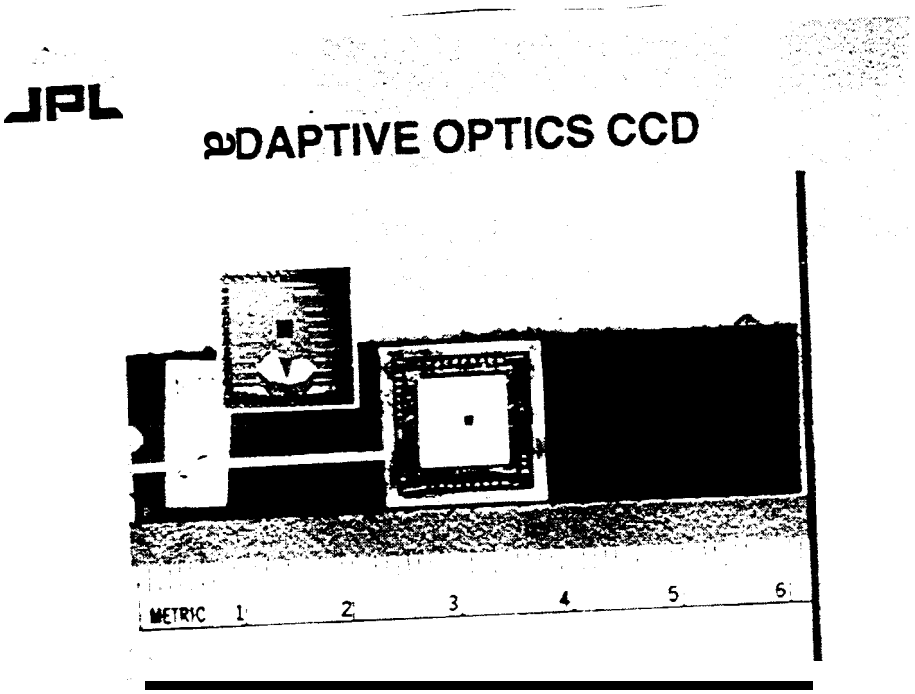
Adaptive optics CCD

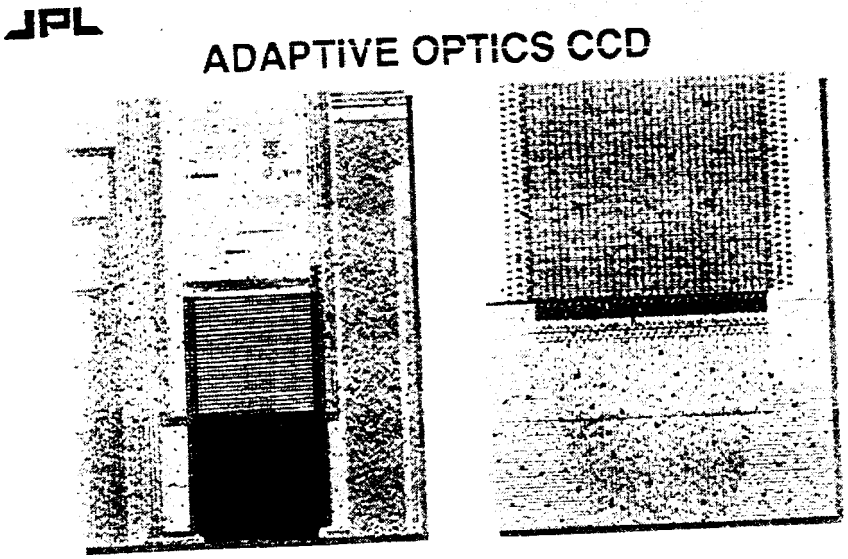
Packaging:

Packaging run/date	Devices packaged	Major results
1. March 1993	Blind packaged: floating diffusion amplifier (FDA) devicess (3)	basic test electronics and cooling uniformity of output gain photon transfer noise ~ 15e rms uncooled Fe55 histogram charge diffusion effect on unloaded and shorted amps
2. September 1993	Blind packaged: FDA devices. Skipper amplifier devices (3)	refined test electronics noise ~ 8e rms cooled Fe55 histogram
3. March 1994	Probed packaged; Skippers (6)	TBD

Adaptive optics CCD

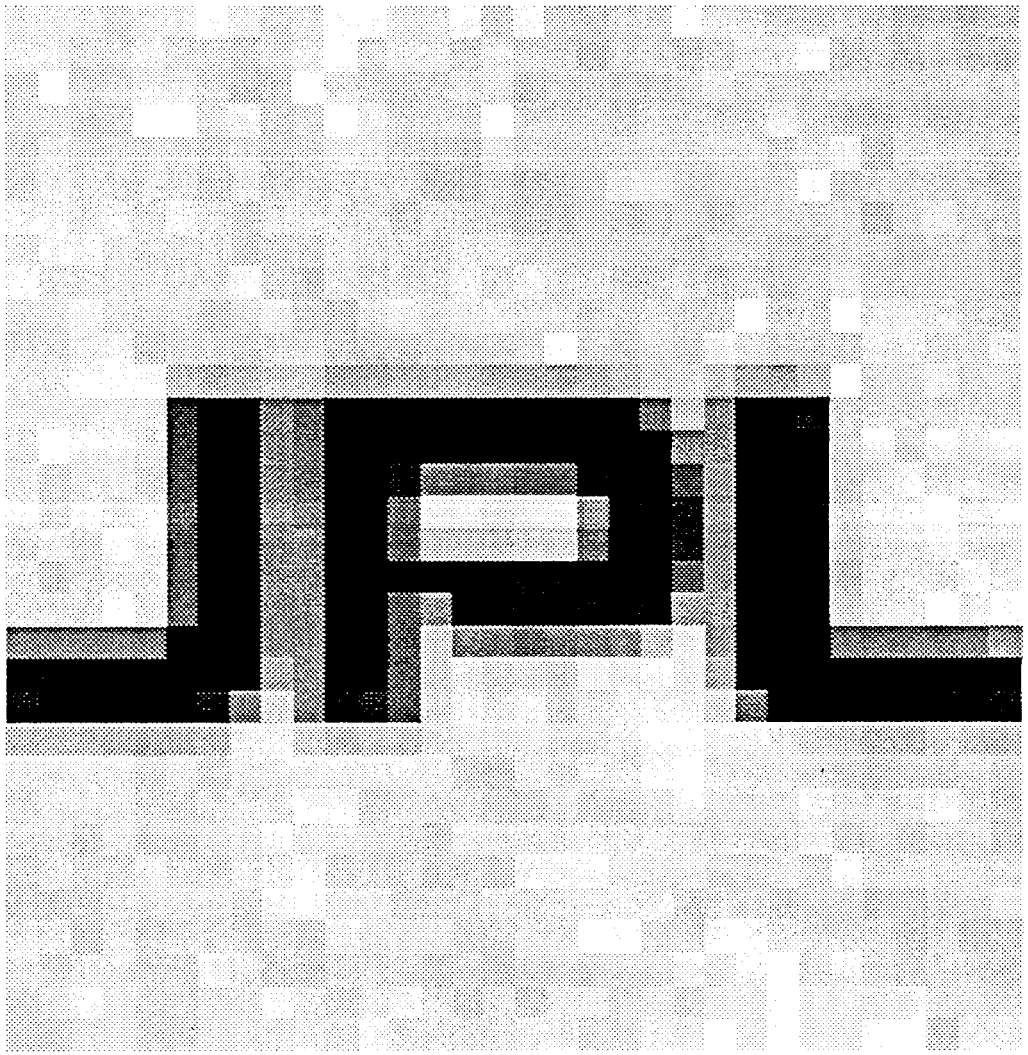
ADAPT2 device:





Adaptive optics CCD

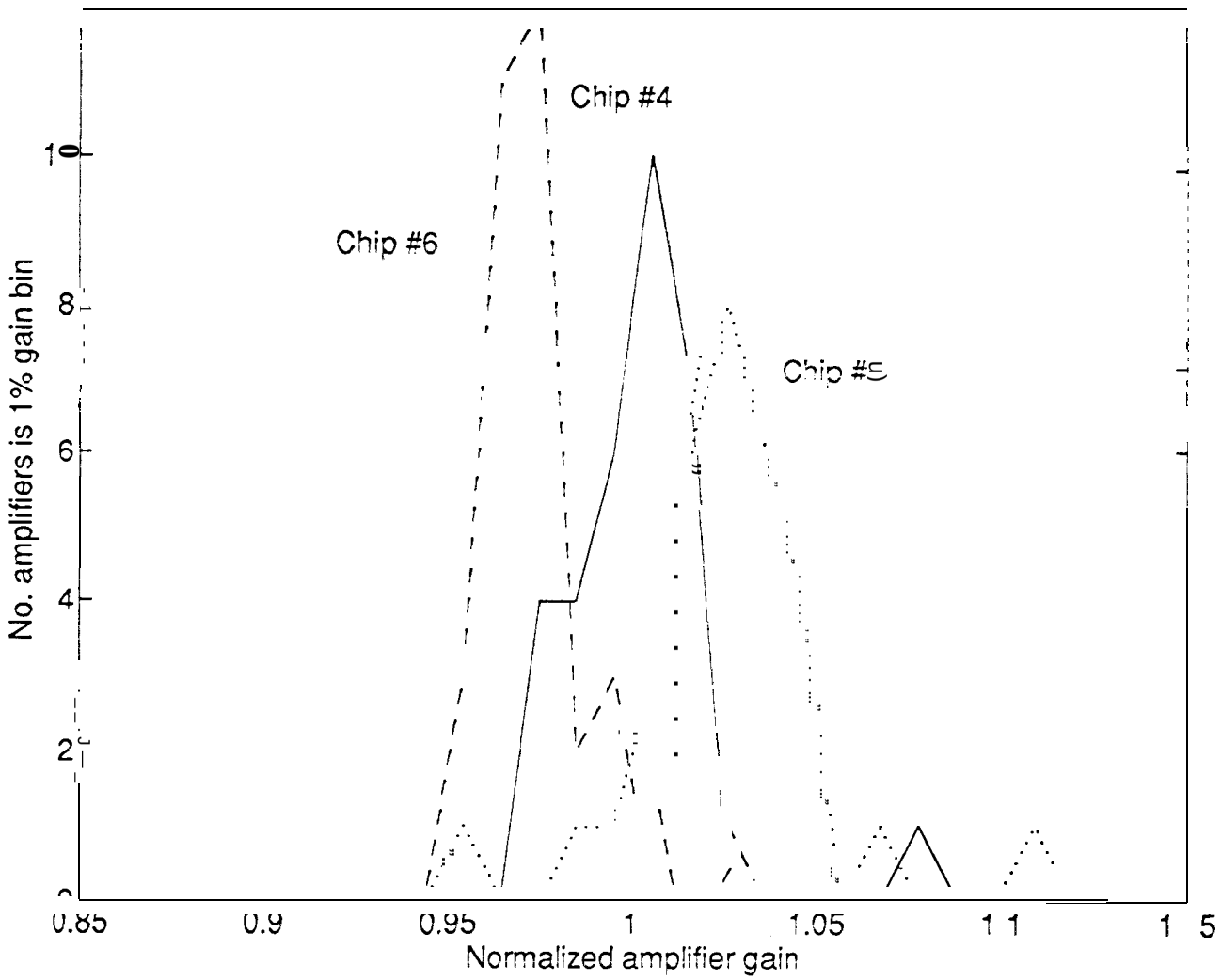
AO CCD image:



Adaptive optics CCD

Amplifier uniformity:

- Fully loaded FDA devices



Adaptive optics CCD

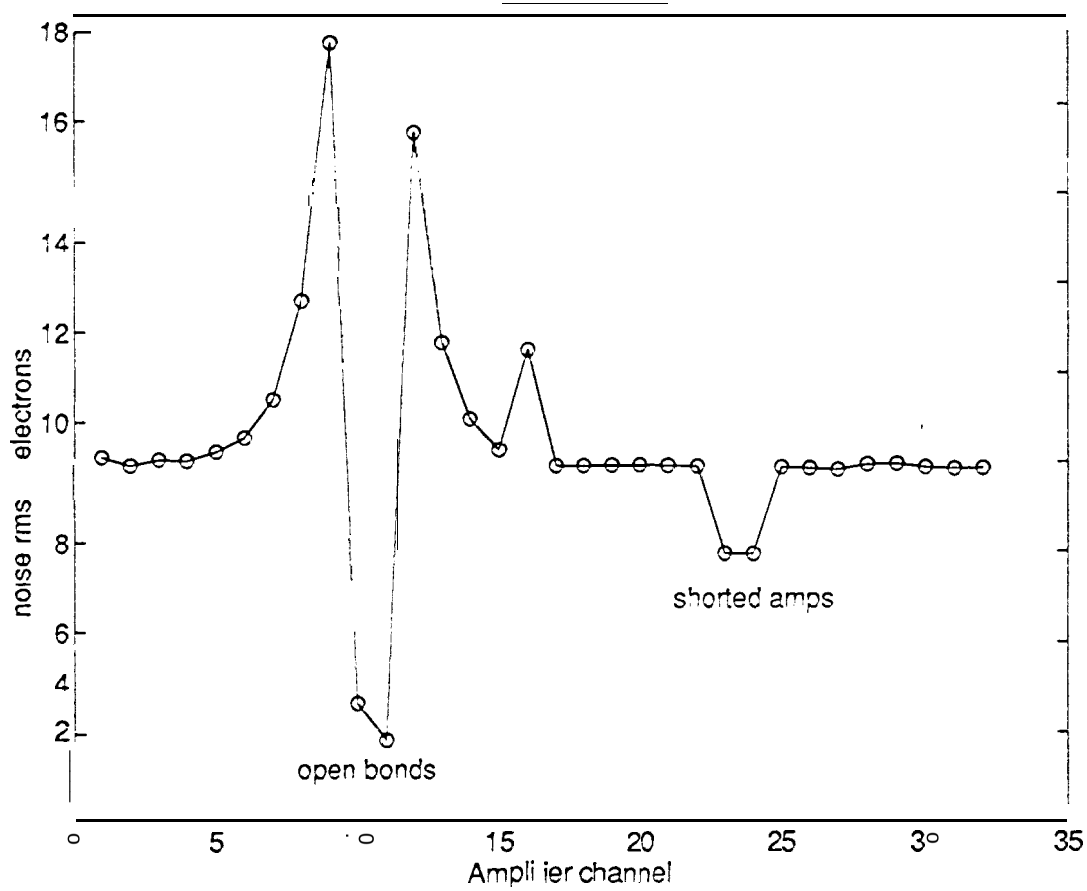
Charge diffusion effects:

- Unloaded and shorted amplifiers causes changes in readout amplifier performance:

  increases read noise

  unloaded amplifiers cause damage to amplifier structu

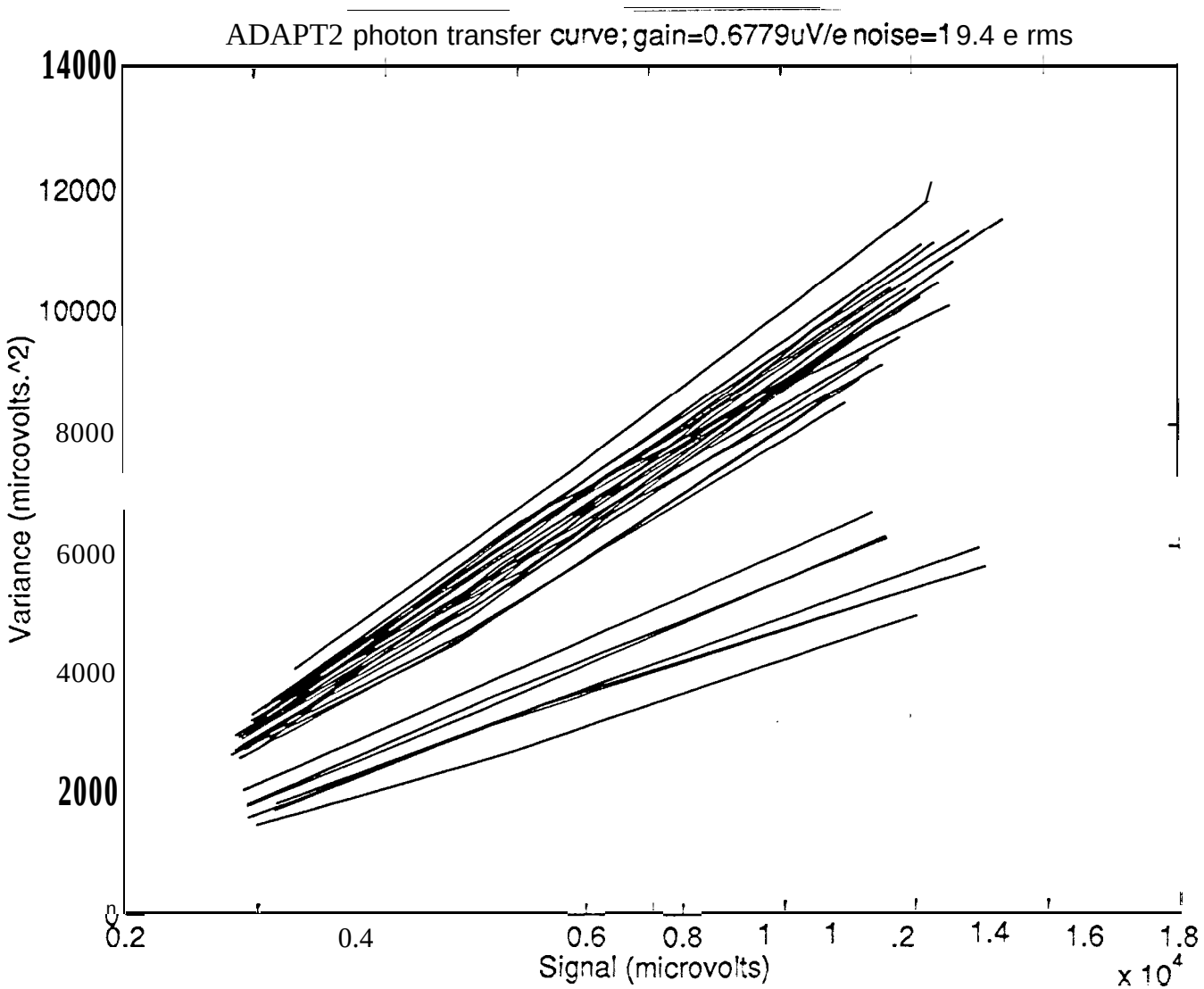
- Observed diffusion effect on Skipper chip



BML 3/6/94

Adaptive optics CCD

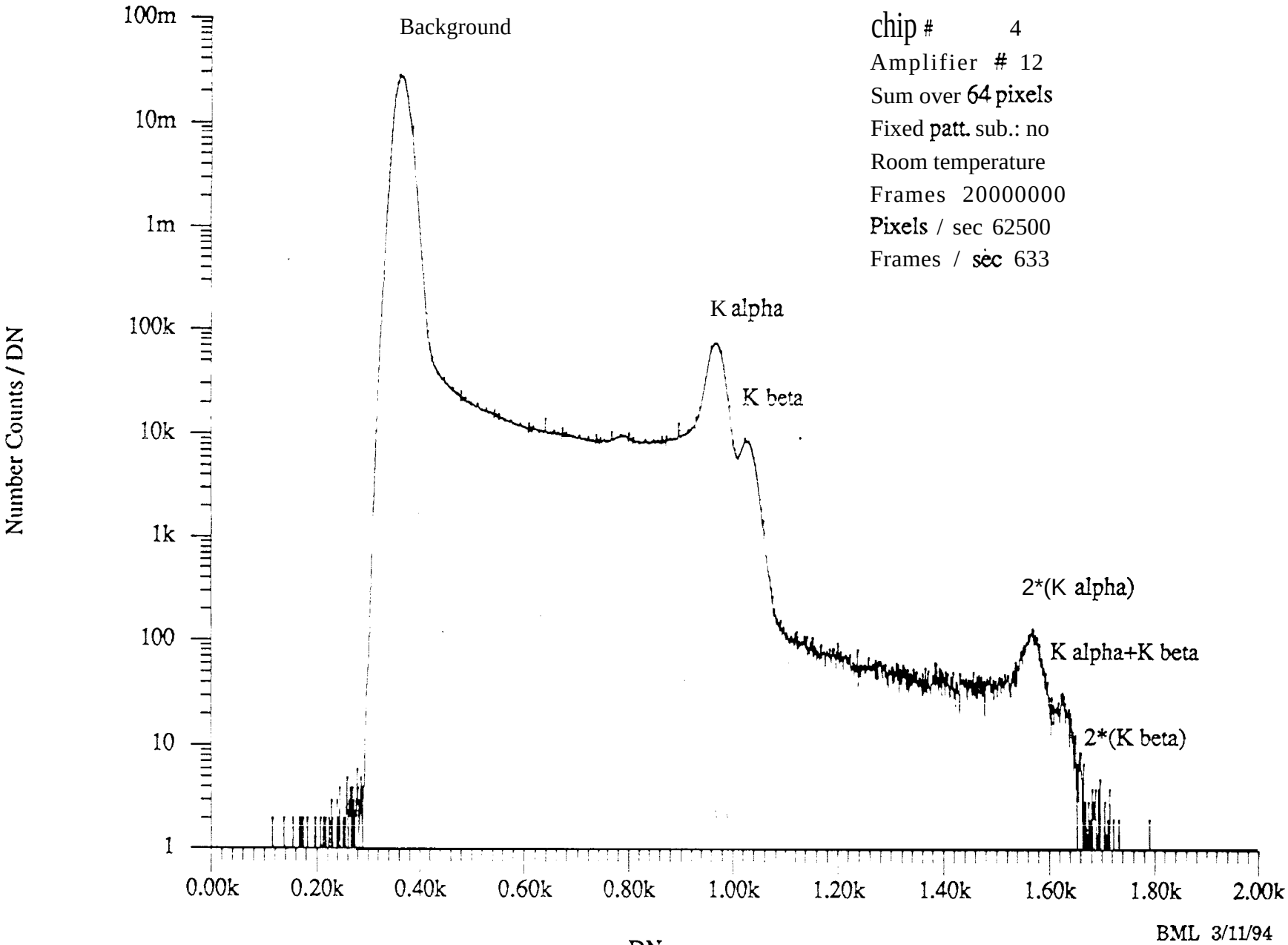
Photon transfer and noise floor:



BML 3/6/94

Adaptive optics CCD

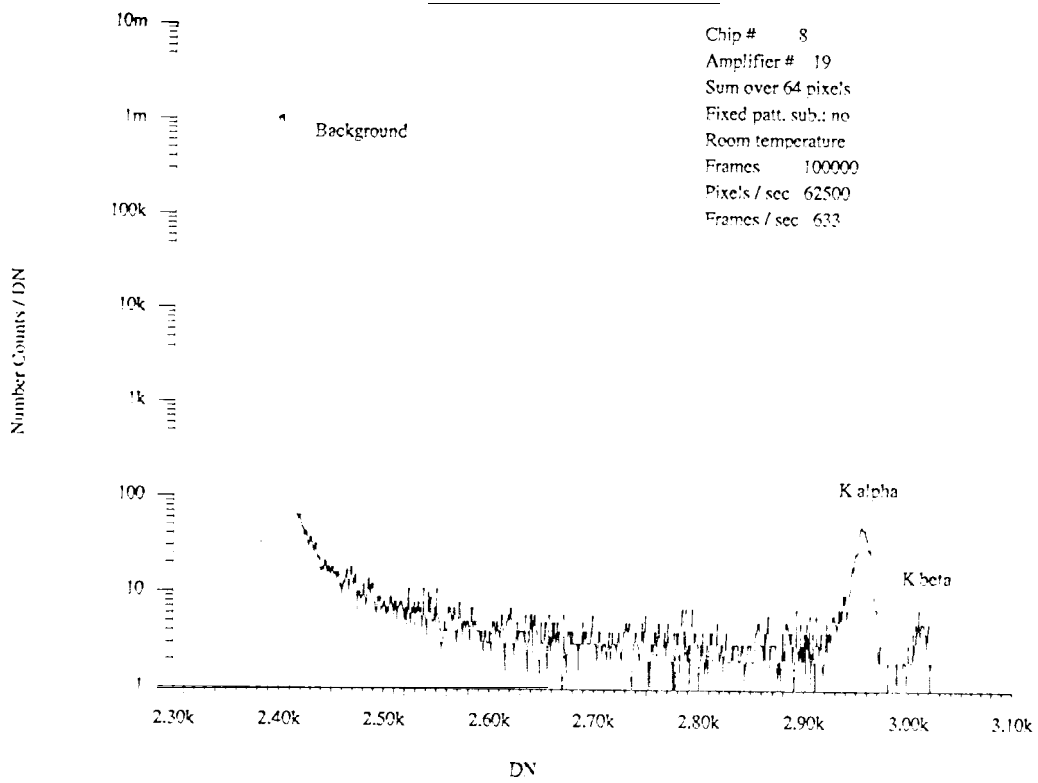
Fe55 Histogram for ADAPT2 chip:

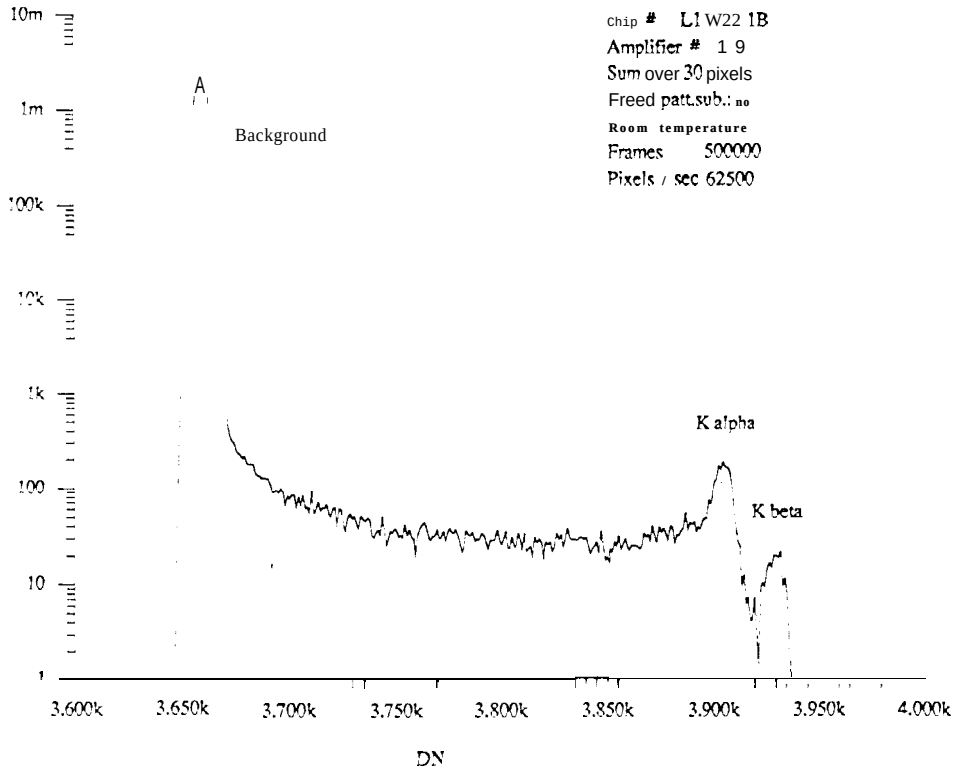


Adaptive optics CCD

Fe55 Histograms on Skipper chips:

- **Single amplifier** read





Adaptive optics CCD

Design improvements:

- separate output amplifiers to reduce charge diffusion

  alternating amplifier outputs top and bottom
- Use CUBIC amplifier structure
- Thinning, backside illumination, and AR coating to enhance quantum efficiency

Adaptive optics CCD

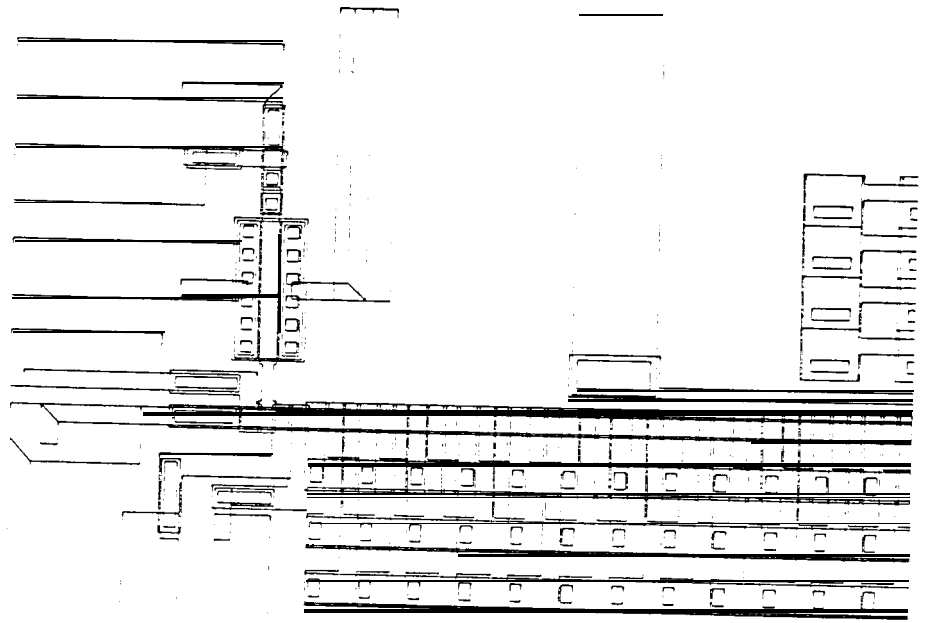
Design improvements(2):

- **CUBIC** amplifier structure

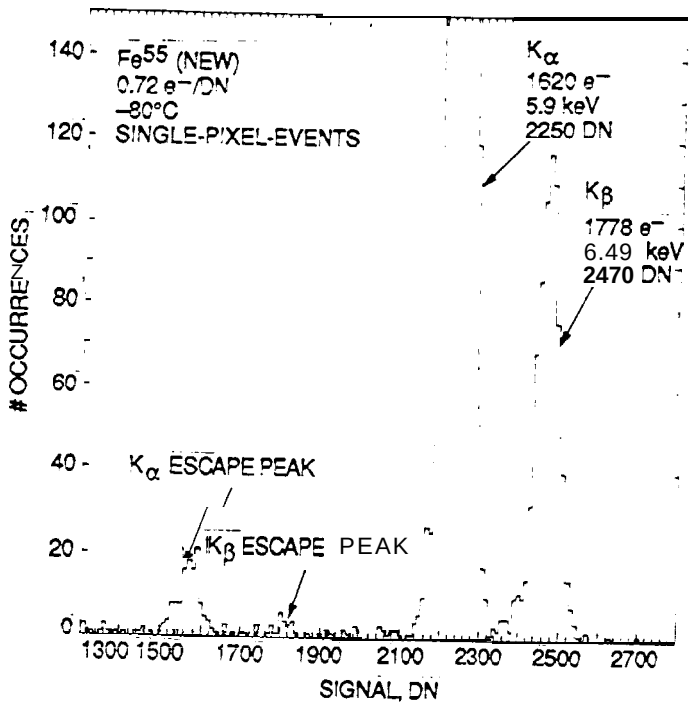
  (**LDD,** super **notch channel,** anti **FET** size optimization)

  noise=2e rms for single read

CUBIC amplifier with Skipper



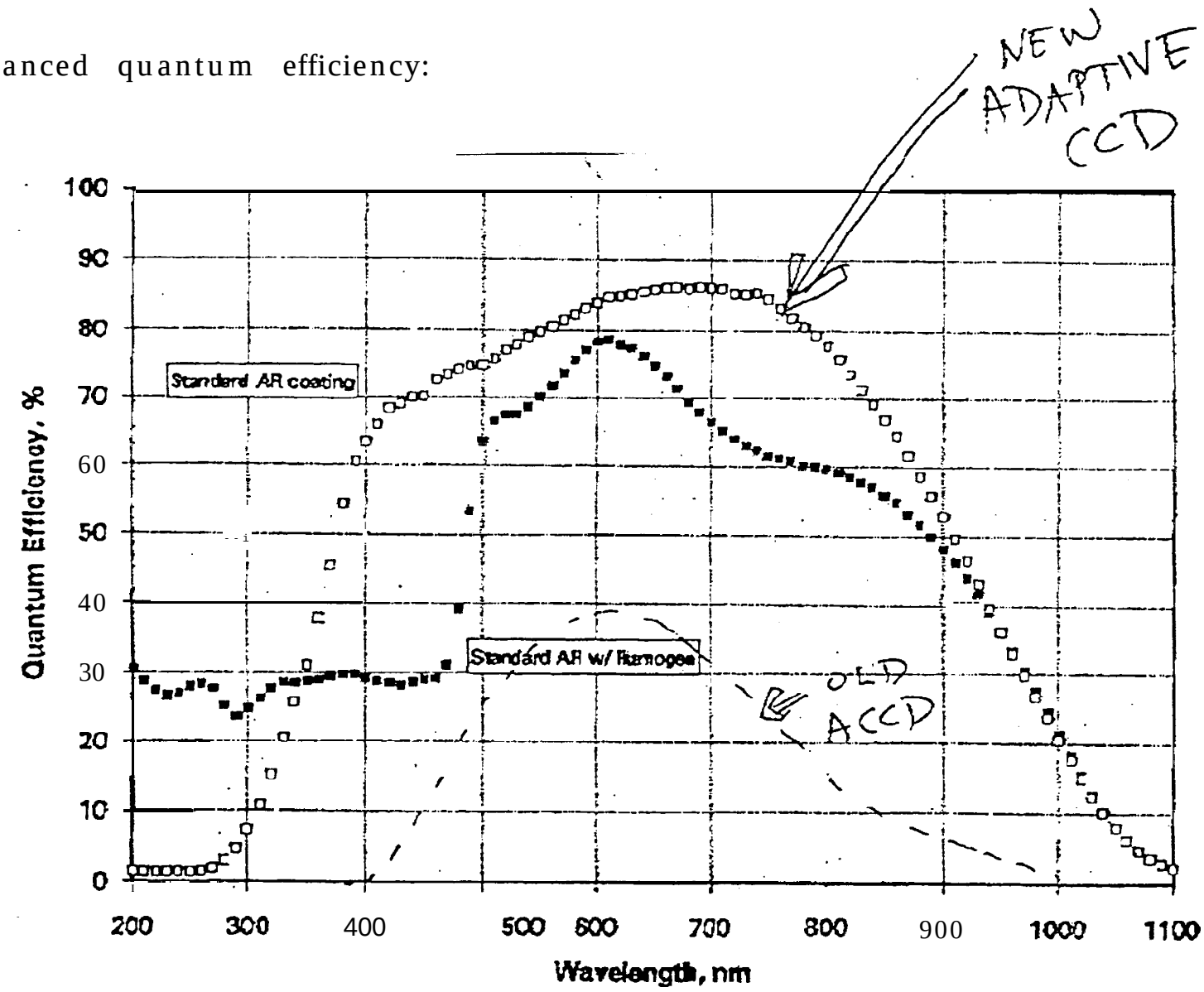
Fe55 **Histogram**



Adaptive optics CCD

Design improvements(3):

■ Enhanced quantum efficiency:



BML 3/6/94

Adaptive optics CCD

Summary and future work:

- Designed and fabricated CCD for AO wavefront sensing

  8e noise floor measured for single read on Skipper amplifier

  uses multiple readout channels to achieve high frame rate with low noise.

- AO CCD is baseline wavefront sensor for Mt. Wilson Hooker telescope

  read out electronics currently in design

- Design improvements to be incorporated in next fabrication run