IU/IUCF APD LightBox Design for NOνA

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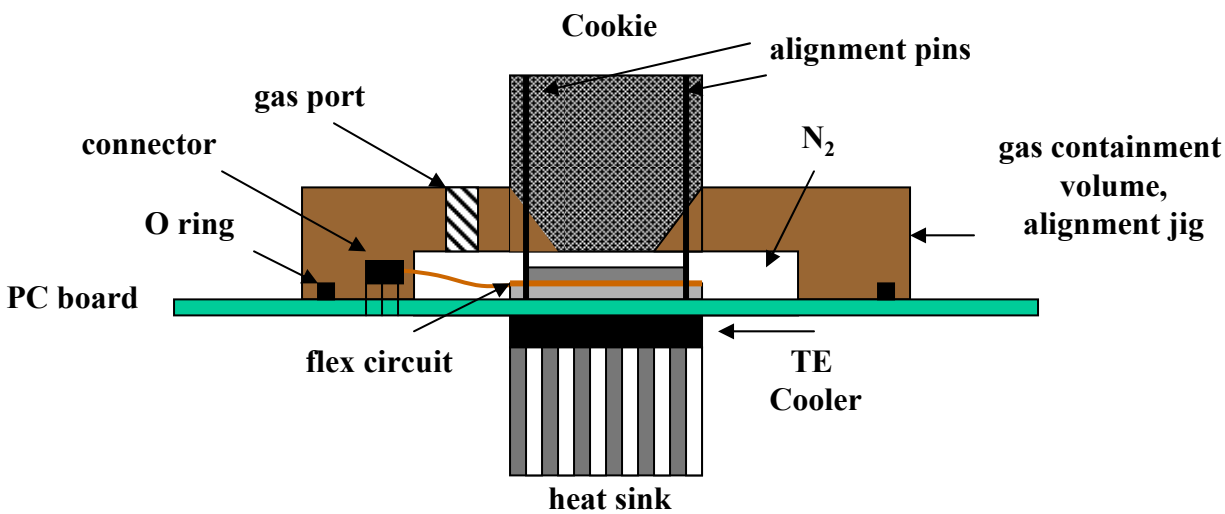
Indiana University

NOνA Collaboration Meeting

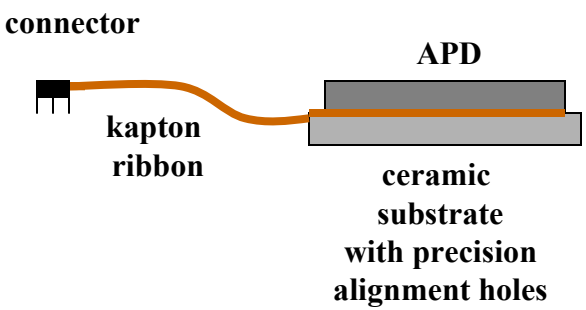
May 5, 2005

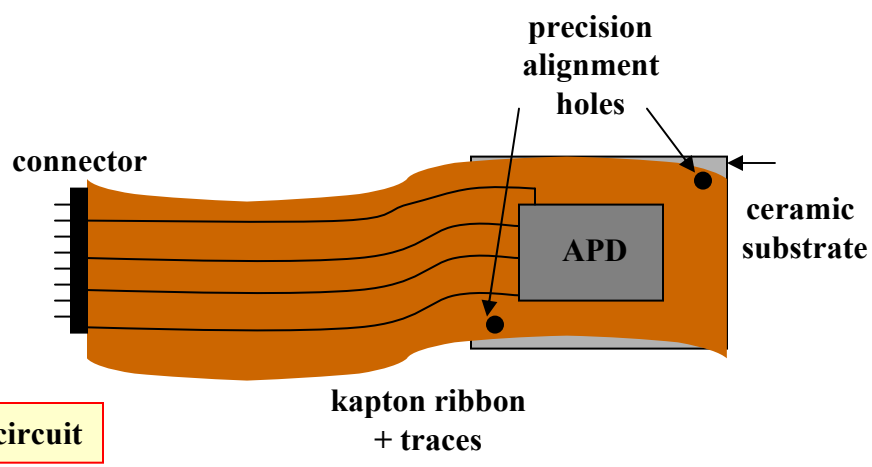
Conceptual Design

APD Mounting



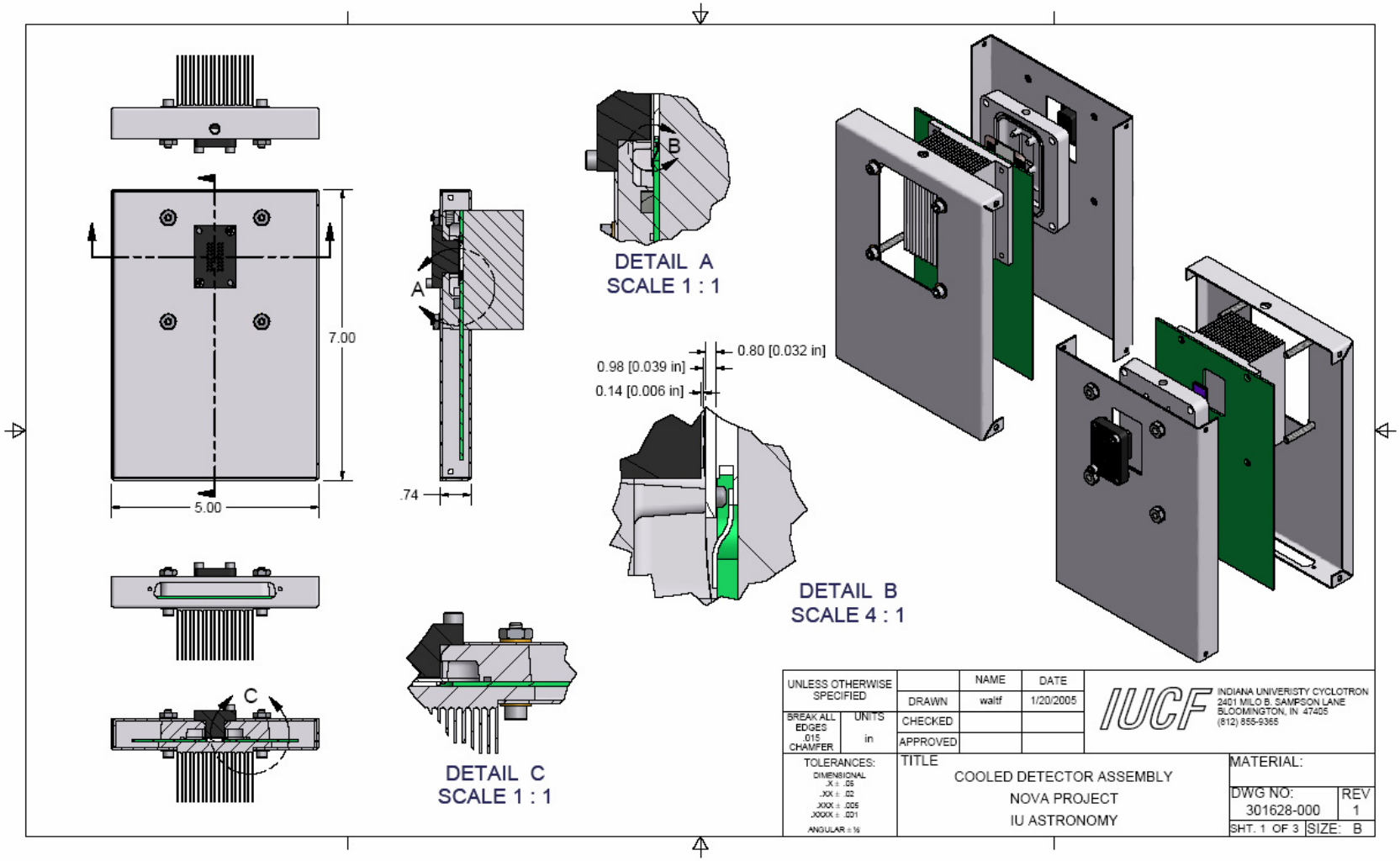
notes:
- alignment using gas enclosure, without reference to PCB
- uses current APD chip design
- flex circuit minimizes heat flow from ambient to APD
- TE cooler mounted directly on heat sink through hole in PCB
- ribbon cable attached to connector in gas containment fixture



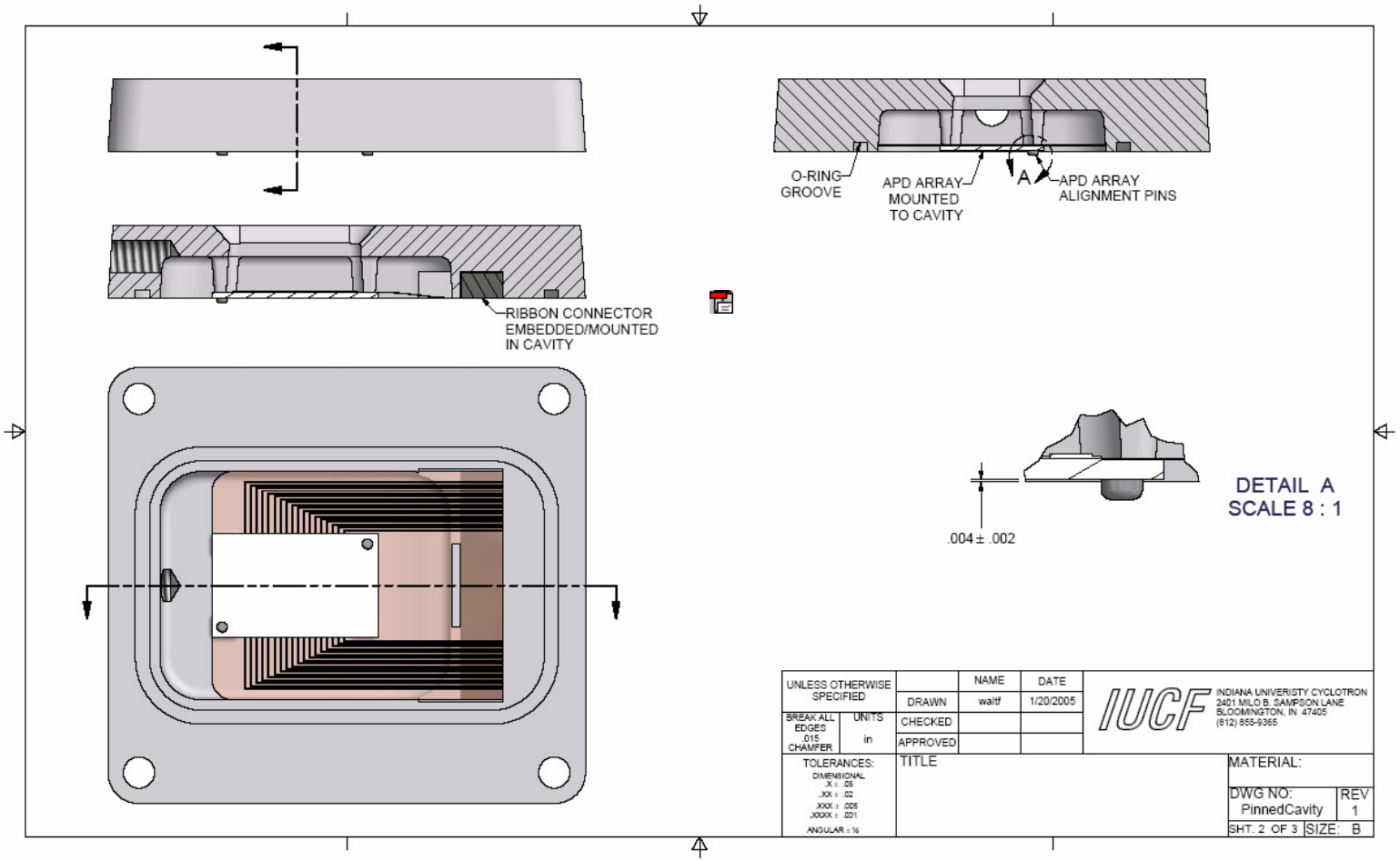


flex circuit

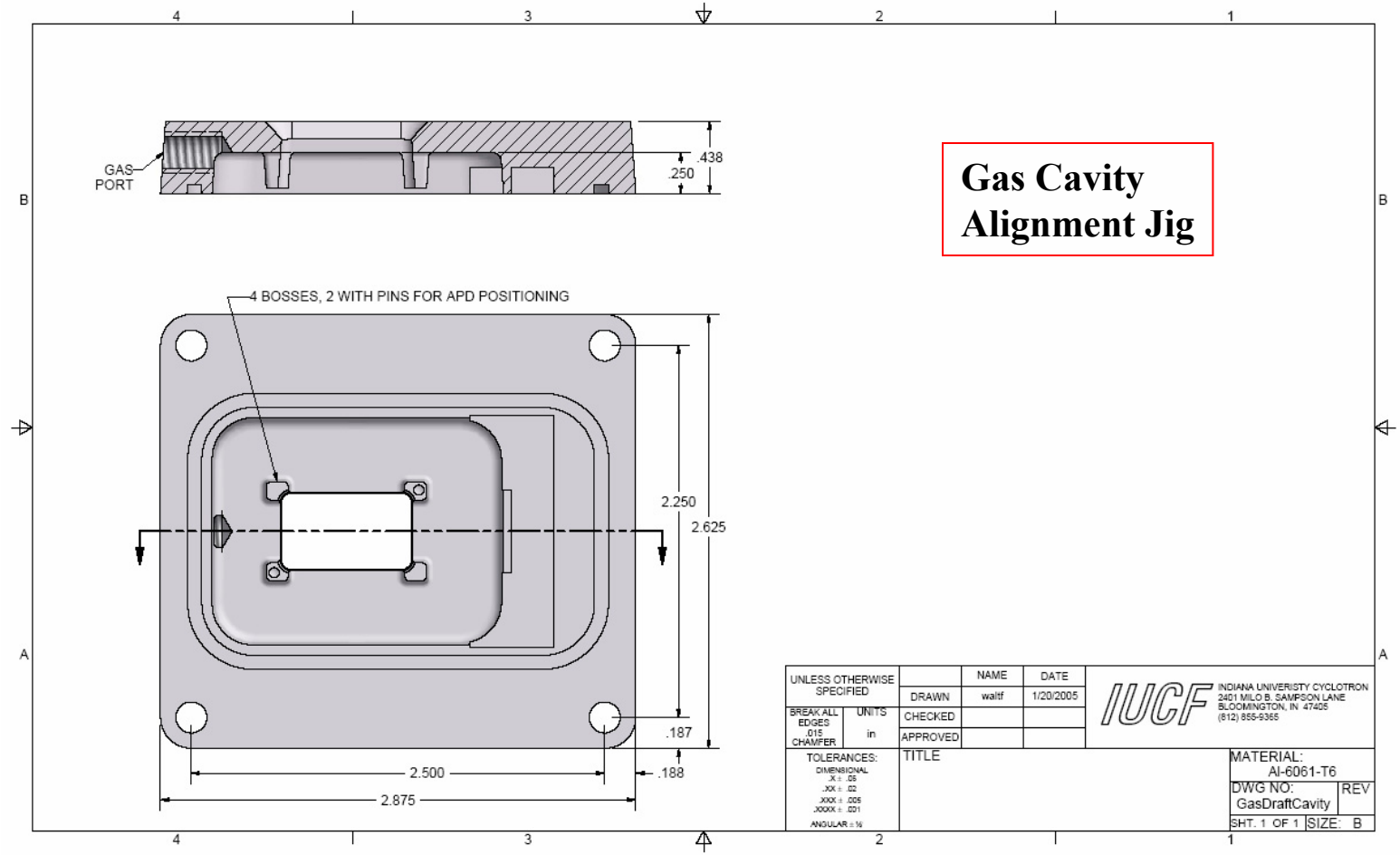
Preliminary Design



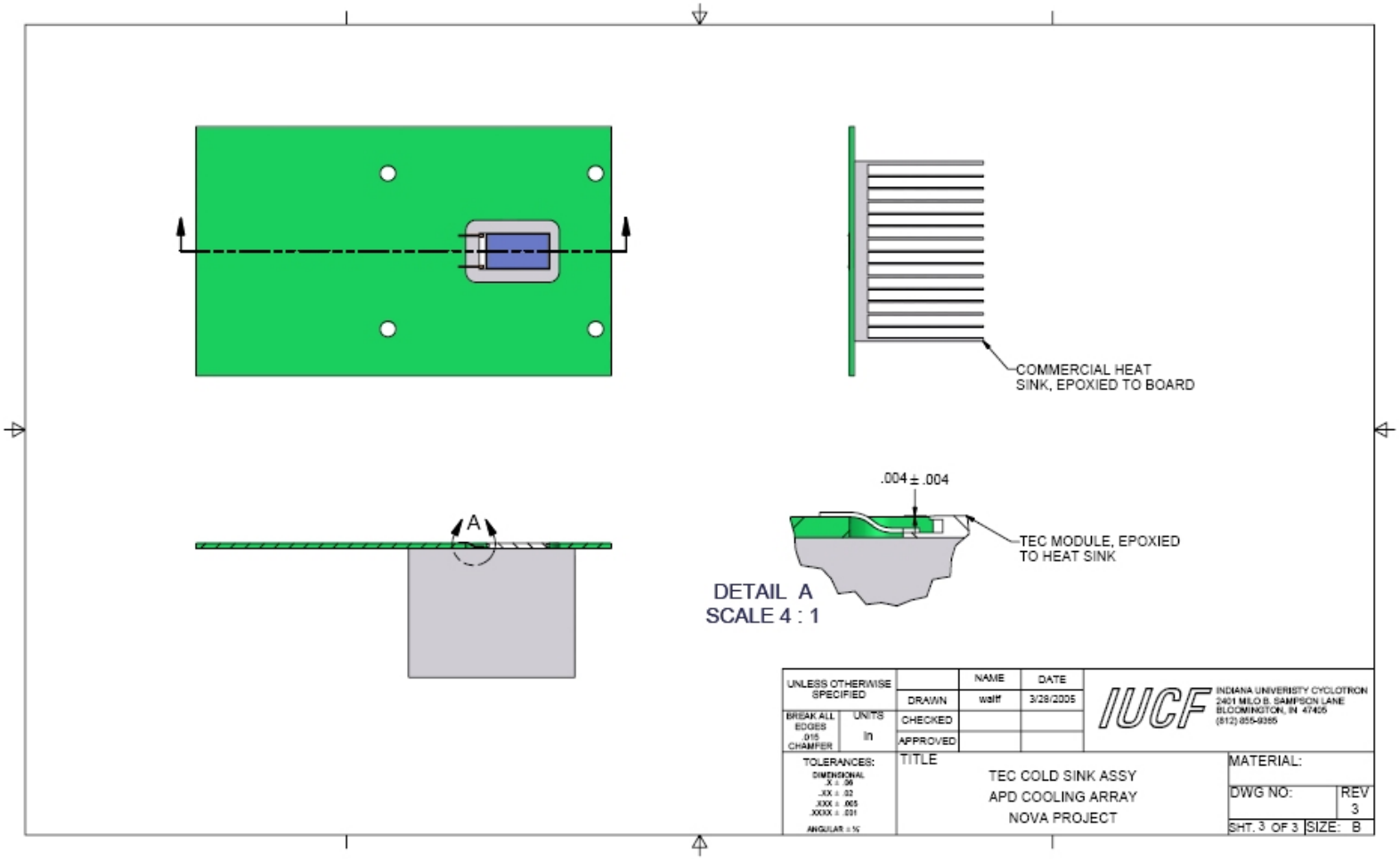
Gas Cavity Alignment Jig



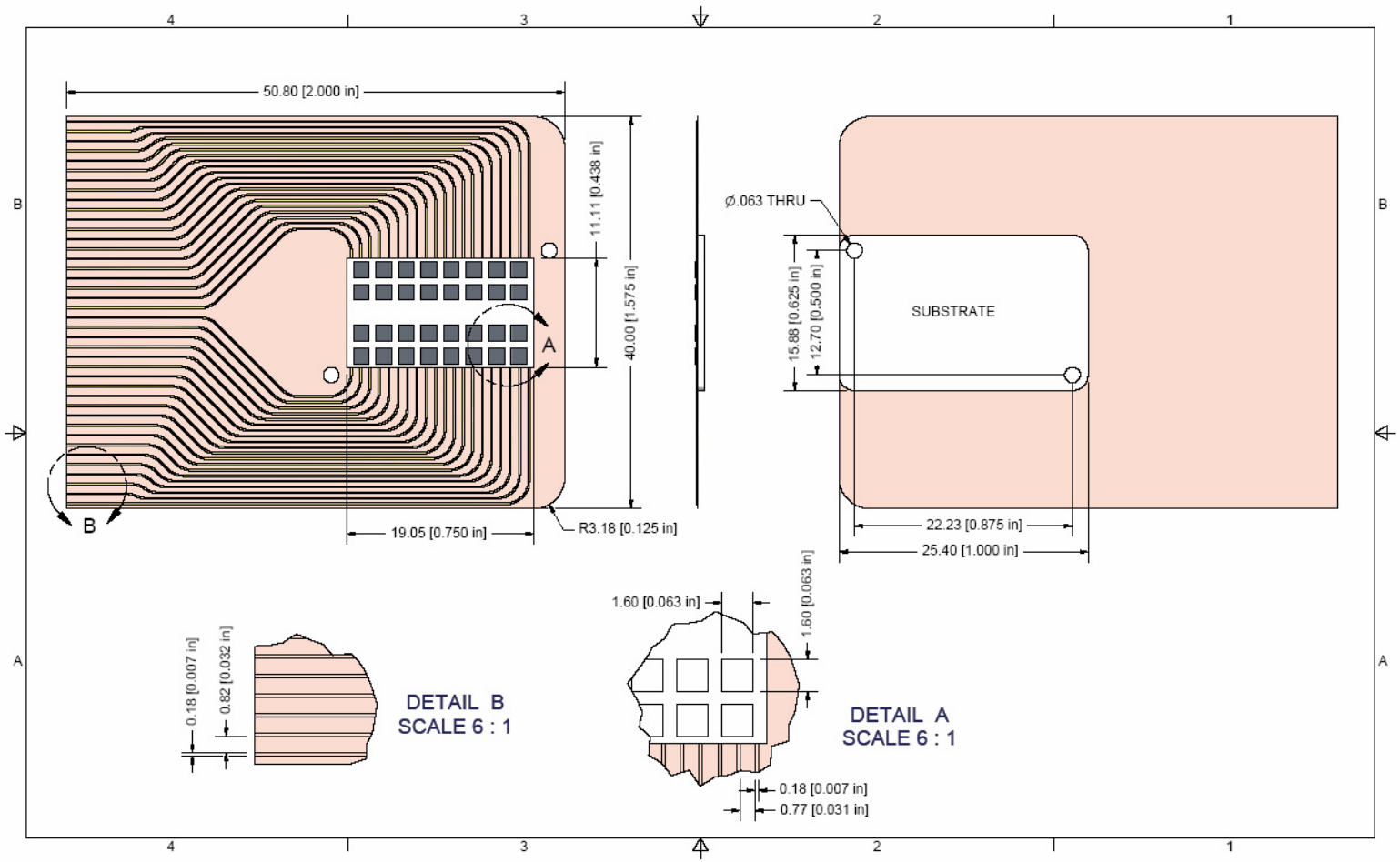
Gas Cavity Alignment Jig



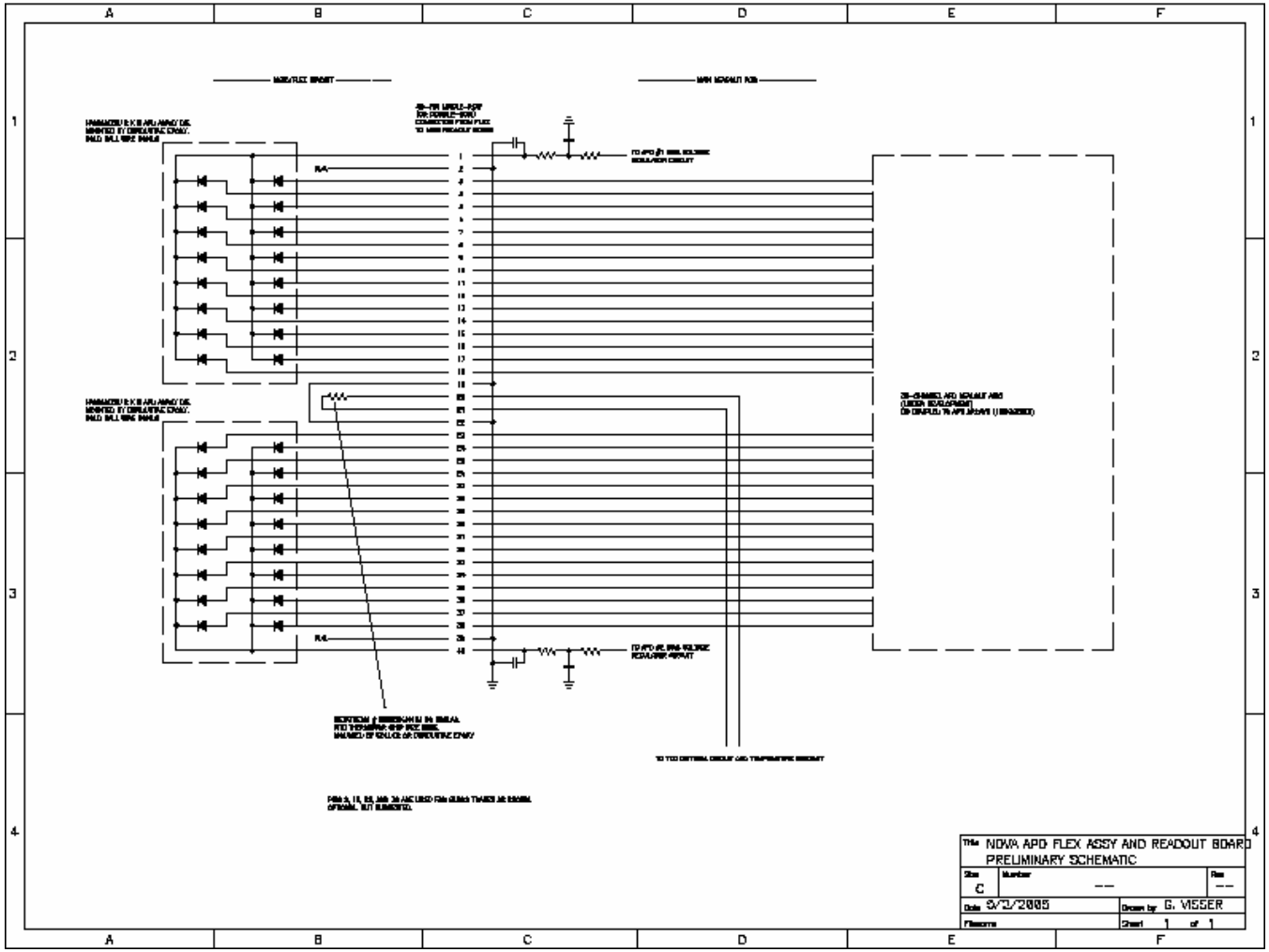
PCB
Heat Sink



Flex Circuit Layout
Preliminary



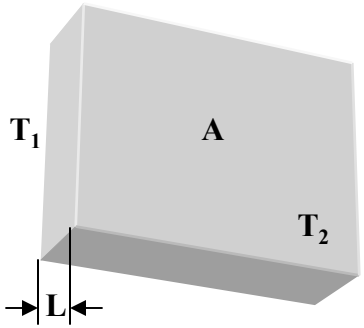
Flex Circuit Schematic
Preliminary



Heat Balance Calculations

Basic Equation

$$Q = k(A/L)(T_2 - T_1)$$



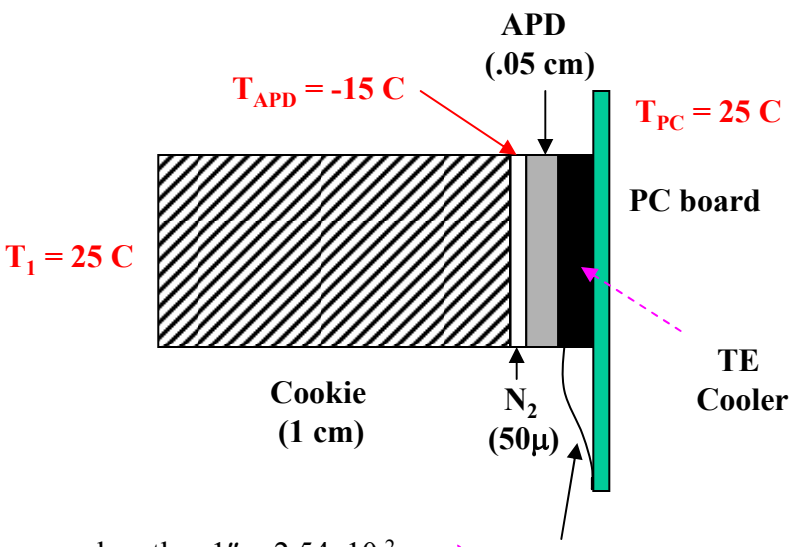
T_1, T_2 = front side, backside temperatures
A = slab area
L = slab thickness

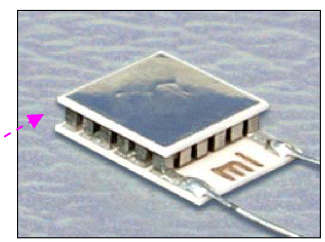
Material Properties: k(W/m/K)

- **ABS optical fiber block: k = 0.188-0.334 W/m/K @ 25C**
- **dry nitrogen: k = 0.024 W/m/K**
- **ceramic APD packaging, assume Alumina: k = 25-30 W/m/K @ 300K**
- **kapton: k = 0.155 W/m/K @ 23C**
- **Cu: k = 400 W/m/K @ 300K**

Heat Balance Calculations

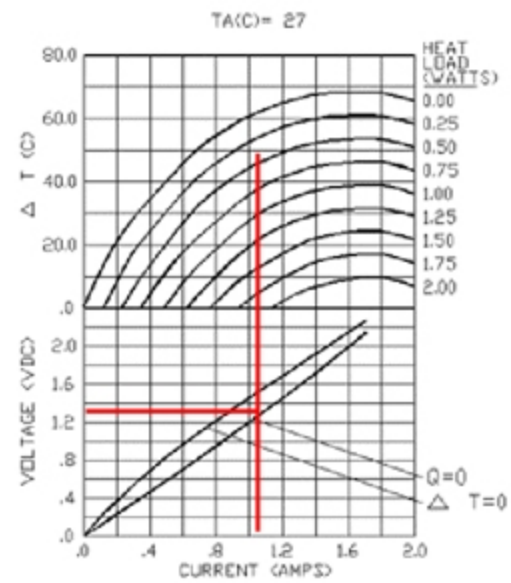
Assume heat transfer constant thru stack





length = 1″ = 2.54×10^{-2} m
width = 0.75″ = 1.91×10^{-2} m
thickness = 0.001″ = 2.54×10^{-5} m
36 copper traces

Environment: 1 atm dry N_2



Typical load conditions for TE cooler,

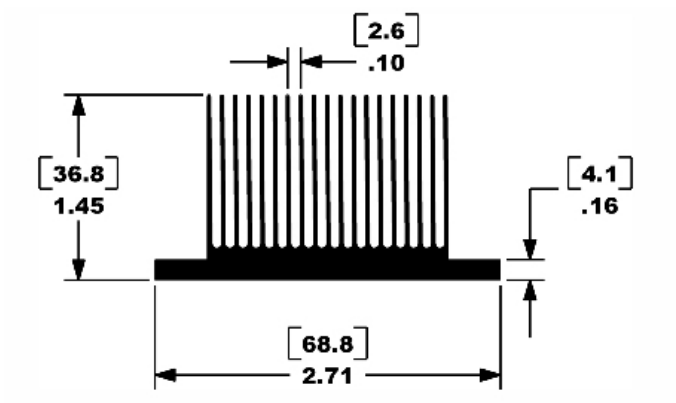
TE cooler must remove **0.35 W** with T_{APD} = -15 C,
$\Delta T = 25 + 15 \approx 40$ C (dominated by heat through cookie)

$$V\,I = 1\,A \times 1.5\,V = 1.5\,W$$

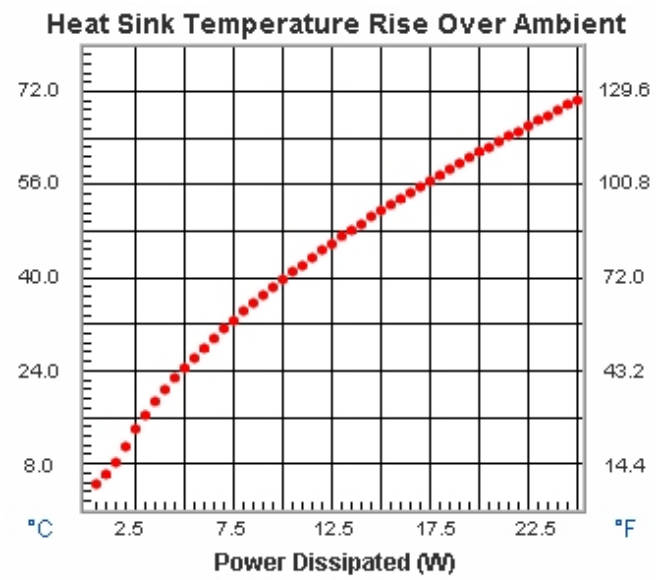
To drive $\Delta T \approx 40$ C: APD stack needs to dissipate ~2W (0.5W from stack, 1.5W from TE cooler)

Heat Dissipation by Box

IU/IUCF design uses commercial heat sink, e.g.



ThermaFlo EH1163



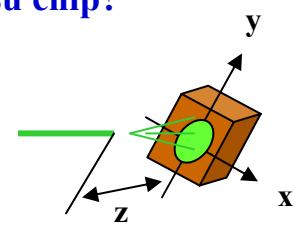
8 C rise in heat sink temperature when dissipating 2W

TE cooler a heat engine: heat sink must be cooled to ambient or TE coolers will fail

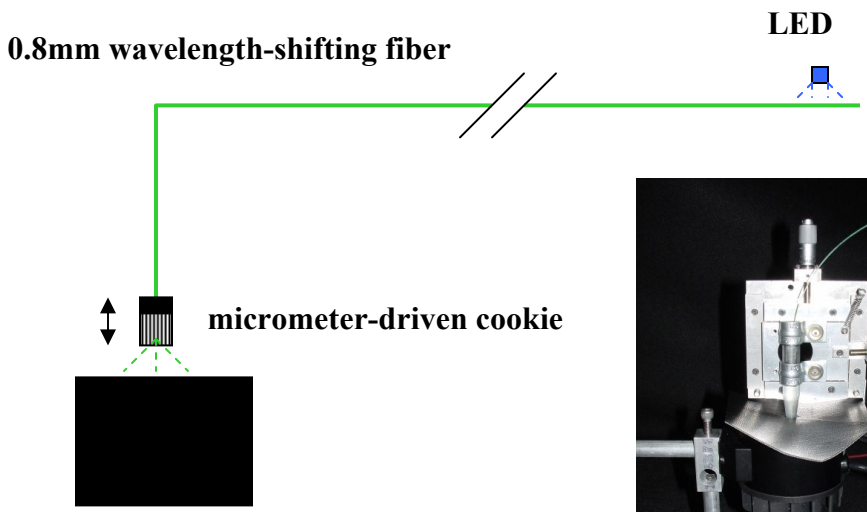
X/Y Tolerance vs Fiber Height

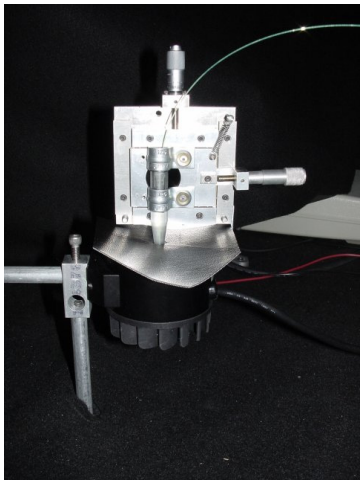
Issue: What are the x/y alignment tolerances required for an APD pixel as a function of fiber height (z) above the chip?

- in particular, are alignment issues a show-stopper for the current Hamamatsu chip?



Apparatus





X/Y Tolerance vs Fiber Height

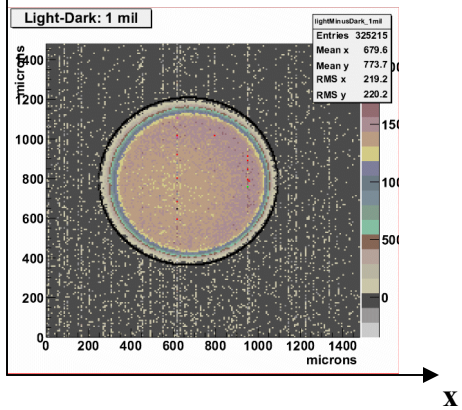
Measurement Sequence:
- dark
- light, 1-5 mils
- dark
- light, 1-5 mils
- dark

Analysis:
- image – (Mean Light – Mean Dark)
- encircled energy – eyeball estimate

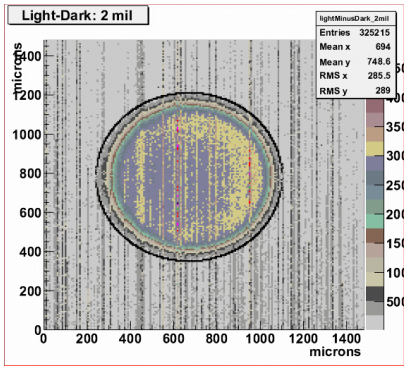
Fiber Irradiance Patterns on CCD + Encircled Energy (solid black circle)

y

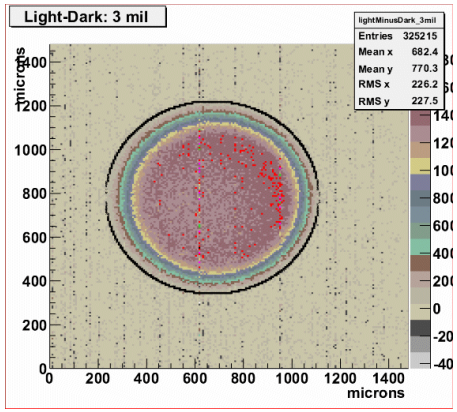
z = 1 mil



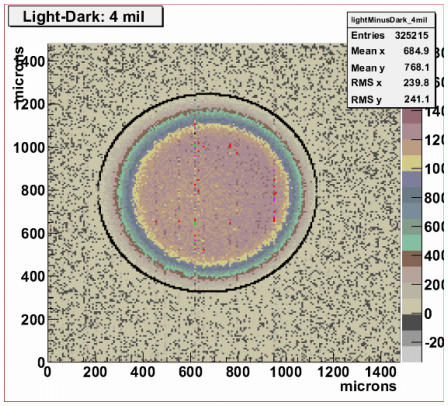
x



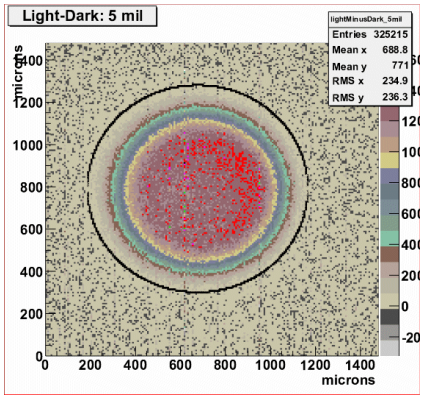
z = 2 mil



z = 3 mil



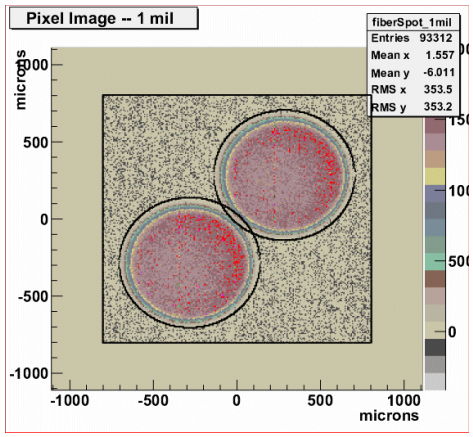
z = 4 mil

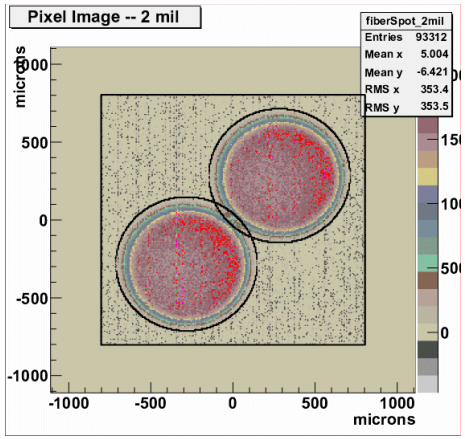


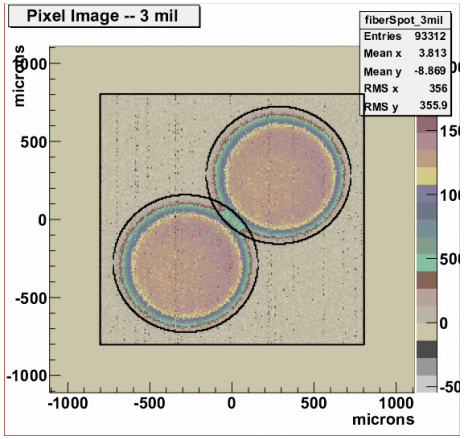
z = 5 mil

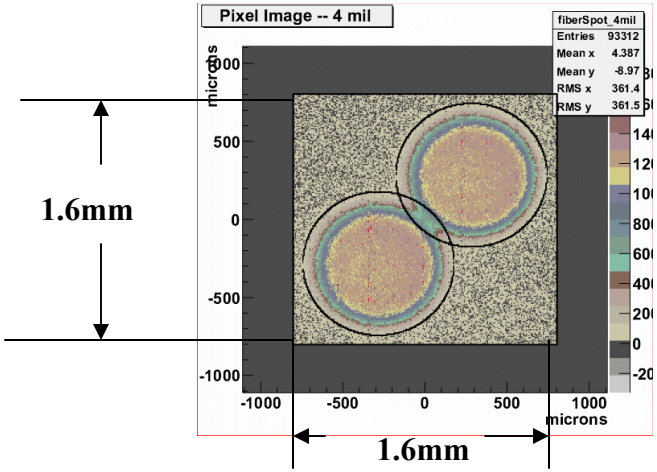
X/Y Tolerance vs Fiber Height

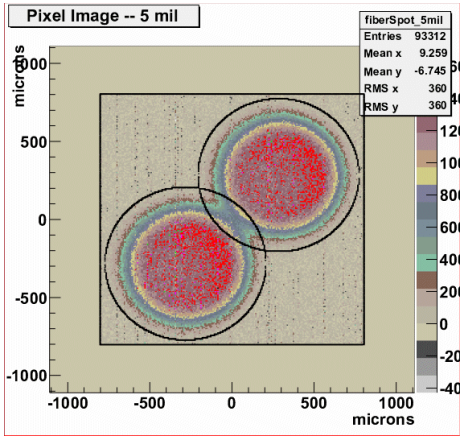
Project pixel images onto simulated 1.6mm Hamamatsu APD pixel





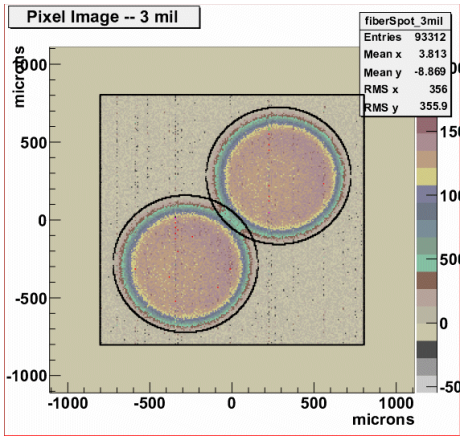




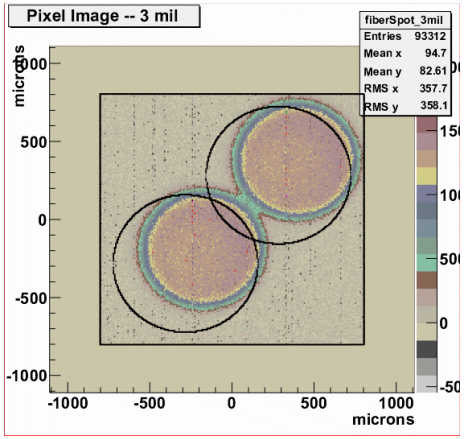


X/Y Tolerance vs Fiber Height

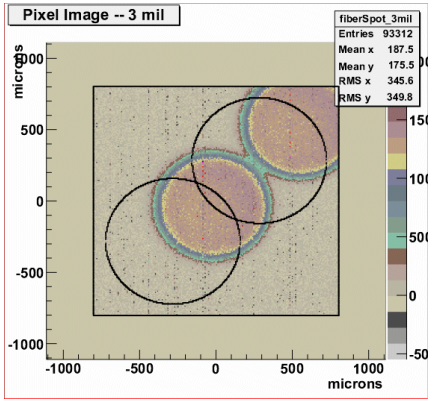
offset = 0



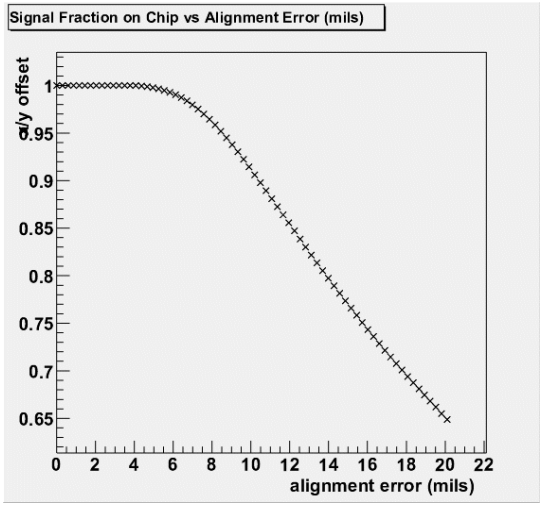
offset = 4 mils



offset = 10 mils

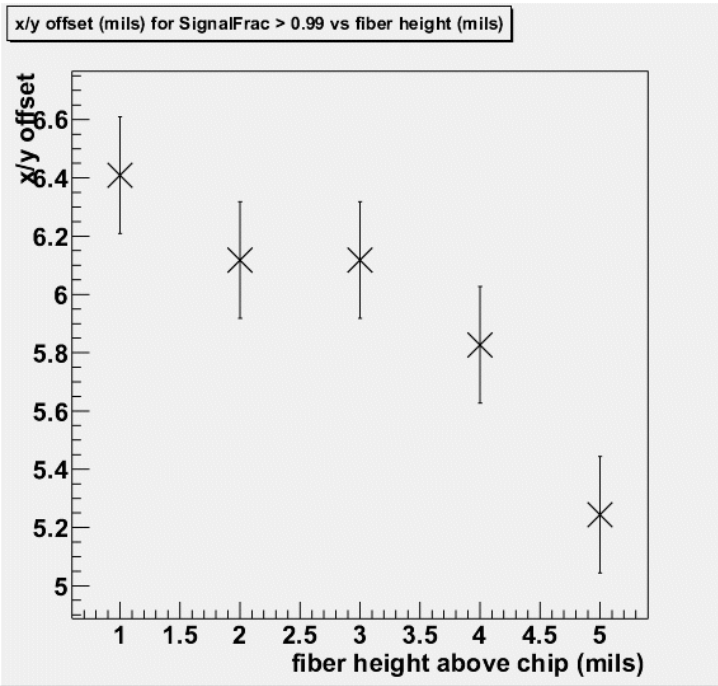


- Add all the signal in the simulated APD pixel
- Move the fiber spots together in (Δx,Δy) increments of 1 CCD pixel (7.4μ)
- Again add all the signal in the simulated APD pixel; normalize result to APD signal with 0 offset
- Signal Fraction vs. Δx (Δy) offset



- Result: (a) most light not at outer edges of fiber spot;
  (b) no light lost from second fiber spot

X/Y Tolerance vs Fiber Height



Tolerance Computation:

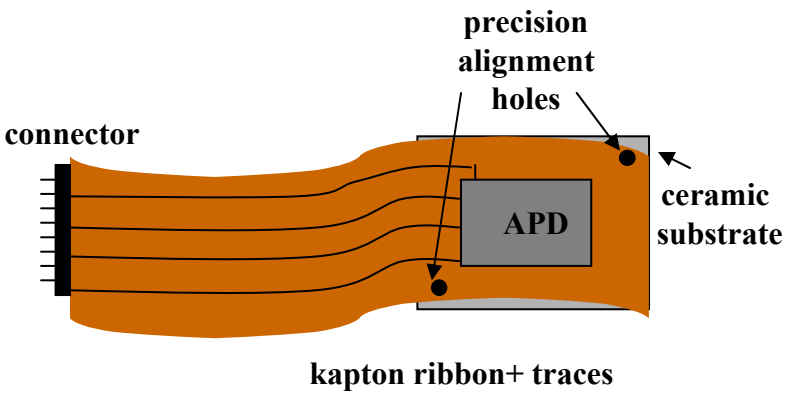
- Find $\Delta x/\Delta y$ offset at which 99% of signal remains on APD pixel as a function of fiber height above APD chip
- Errors: crude estimate of eyeball determinations of encircled energy, backgrounds, etc.

Conclusions:

- There do not appear to be x/y alignment tolerance show-stoppers associated with the current Hamamatsu APD pixel geometry
- Implication: it should not be hard to hold x/y alignment tolerances to several mils with industry standard mechanical mounting procedures
- Careful R&D is necessary to verify these conclusions

R&D Issues

1. Mechanical/Thermal Design:
   - prototype gas containment volume/cookie –
     - alignment issues
     - gas containment integrity
     - suitability for injection molding/machining
   - prototype APD stack --
     - thermal issues

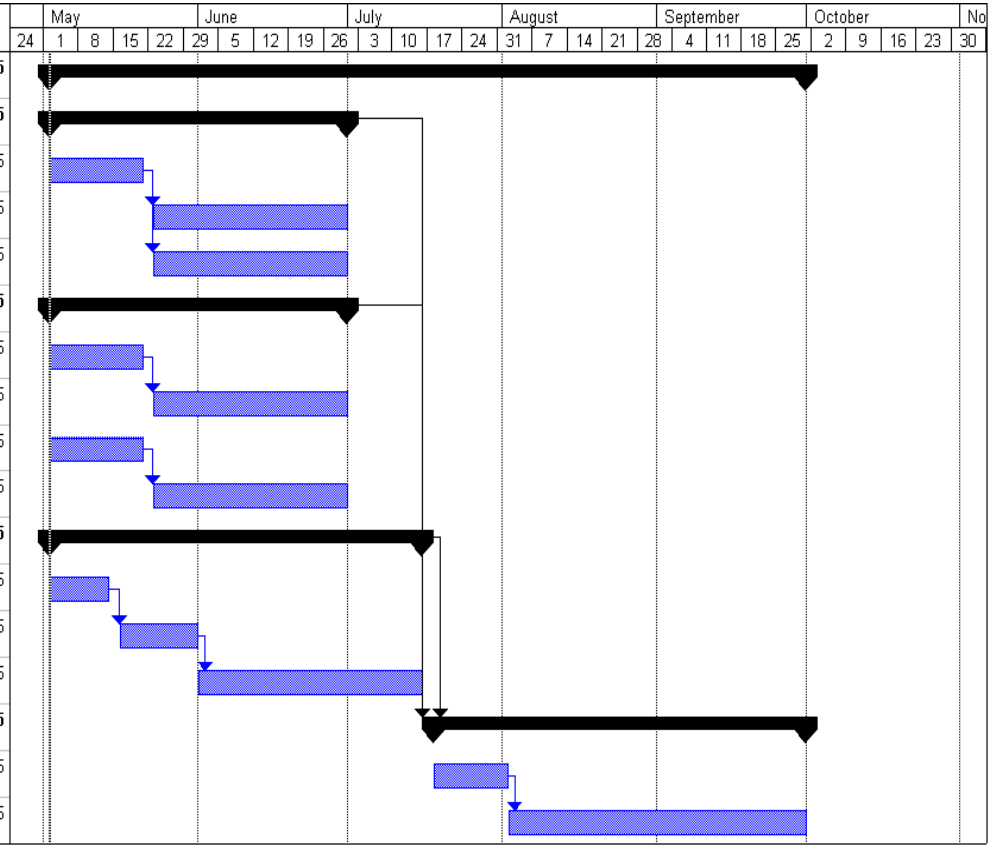


2. Flex Circuit:
   - can Fermilab (SciDet) build a flex circuit that
     - wire bonds APD chip to traces on kapton ribbon, glues the kapton ribbon to ceramic substrate, and keeps registration between pixels and precision holes to 3-4 mils? (done routinely in industry; capable of 1 mil setup)
     - maintains stack height between 2-4 mils (not a tough spec)
     - is this adequate to align pixels relative to precision holes to 3-4 mils? (measurements say yes)
   - can Fermilab build 20-30k of these flex circuits, holding tolerances, for a price NOνA can afford?

3. Detector R&D:
   - R&D on this design this summer at Indiana/Fermilab/? would determine
     - whether the design works
     - the resources required to produce 12,000 channels for the near detector prototype

Prototype Schedule

ID	Task Name	Duration	Start	Finish
1	**prototype light box for NOVA**	**110 days**	**Mon 5/2/05**	**Fri 9/30/05**
2	**prototype mechanical/thermal design**	**44 days**	**Mon 5/2/05**	**Thu 6/30/05**
3	mechanical/thermal engineering	15 days	Mon 5/2/05	Fri 5/20/05
4	procure commercial parts	29 days	Mon 5/23/05	Thu 6/30/05
5	machine prototype parts	29 days	Mon 5/23/05	Thu 6/30/05
6	**prototype controller & dummy readout design**	**44 days**	**Mon 5/2/05**	**Thu 6/30/05**
7	temperature controller engineering	15 days	Mon 5/2/05	Fri 5/20/05
8	procure parts	29 days	Mon 5/23/05	Thu 6/30/05
9	dummy readout board engineering	15 days	Mon 5/2/05	Fri 5/20/05
10	make/stuff board	29 days	Mon 5/23/05	Thu 6/30/05
11	**flex circuit design**	**55 days**	**Mon 5/2/05**	**Fri 7/15/05**
12	schematic flex circuit layout	10 days	Mon 5/2/05	Fri 5/13/05
13	flex circuit engineering	12 days	Mon 5/16/05	Tue 5/31/05
14	flex circuit prototype	33 days	Wed 6/1/05	Fri 7/15/05
15	**light box prototype**	**55 days**	**Mon 7/18/05**	**Fri 9/30/05**
16	assembly	11 days	Mon 7/18/05	Mon 8/1/05
17	testing	44 days	Tue 8/2/05	Fri 9/30/05



Fermilab task

Indiana Costs without Fermilab Flex Circuit Costs

Indiana engineering costs relatively modest because conceptual engineering already completed

Required Resources

	rate	hours	cost
Engineering			
machanical/thermal (W.Fox)	$48.42/hr	80	$3,874
electrical (G.Visser)	"	120	$5,810
Supplies/Equipment			
custom circuit board			$2,000
chips, sensors, TECs			$3,000
miscellaneous parts			$2,000
Contingency			$3,000
Total			**$19,684**

Indiana Contributions

	rate		cost
Machining Prototypes/2 passes	$30/hr	80 hr	$2,400
Technician			
B.Adams	$4,030/mo	3 mo	$12,090
Total			**$14,490** *

* does not include completed conceptual engineering costs

HAMAMATSU QUOTATION

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To: **Fermi Labs**
P.O. Box 500
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Delivery: **see below**
Subject:

Line Item QTY Unit Price Lead Time
1
S8550 in chip form
[S8550 in chip form] 10 - 12
$495.67
3 weeks aro

$31/ch
=12.4 x $2.50

potential show stopper

Comments:

Attachments:

Please note:
Purchase Orders may be subject to Sales and Use Tax.

The pricing on this price quotation is valid for 30 days.

The above items are manufactured in Japan