LBNL/APS Collaboration on Fast CCD Development
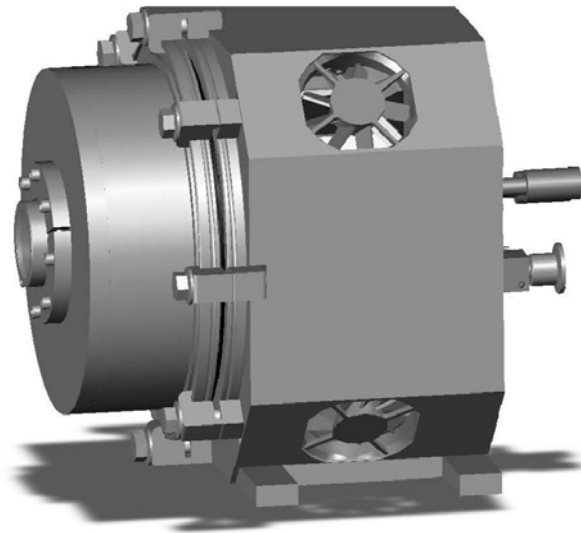## *10-25-2006*

By: John Weizeorick

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Argonne National Laboratory

Advanced Photon Source

X-Ray Science Division

Beamline Technical Support Group

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Station Identification

- **Beamline Technical Support**
  - Who
    - *Patricia Fernandez*
    - *Kevin Beyer*   *Lisa Gades*   *John Lee*
    - *Troy Lutes*   *Tim Madden*   *Antonino Miceli*
    - *Diane Morgan*   *Steve Ross*   *Rick Spence*
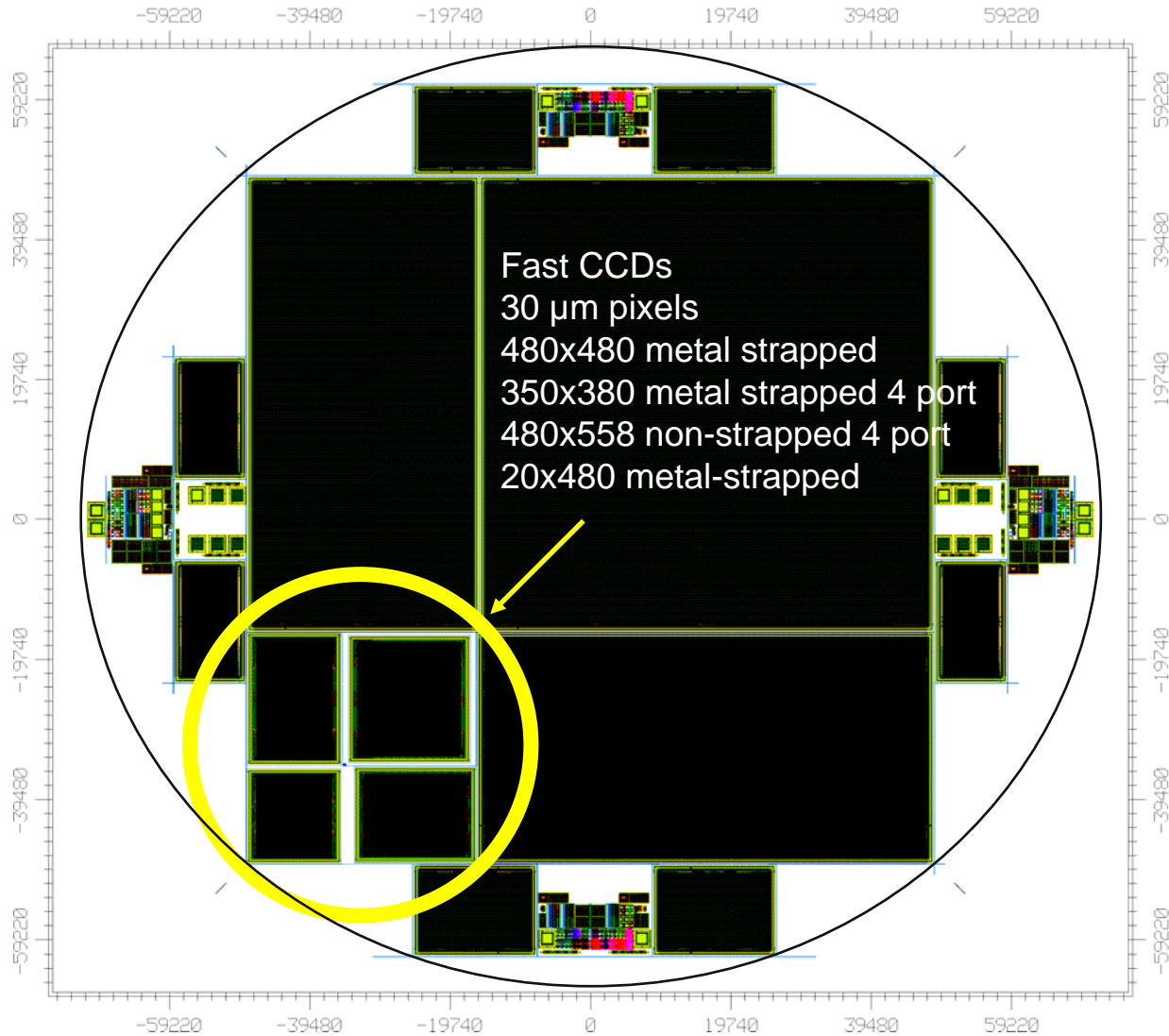   - *John Weizeorick*

  - What
    - *Detector Pool*
    - *Equipment Pool*
    - *Point-of-contact between APS user community and Argonne/APS service groups and contractors*
    - *Provide assistance to beamline staff on construction, upgrade, repair , etc*
    - *Detector development and beamline instrumentation*

FCCD Project - History

- SNAP - (Supernova / Acceleration Probe) – Proposed space based telescope
  - SNAP CCD
    - *Thick, (>200 µm), Fully depleted, back-illuminated CCD imager*
    - *SNAP will use a CCD Mosaic camera (half-billion pixel imager)*
  - SNAP Readout IC
  - Both being Developed by Custom Integrated Circuits group at LBNL lead by Peter Denes
- Howard Padmore (ALS) and Peter Denes at LBNL
  - Realized SNAP CCD has characteristics that are useful for X-ray CCD
    - *Back-illuminated – Higher optical quantum efficiency*
    - *Thick substrate – Enough mechanical structure for fiber optic taper, or it can be used for direct x-ray detection.*
  - Ideal X-ray CCD needs faster readout than SNAP IC's can provide
    - *Their design added almost column-parallel readout*
  - To make FCCD affordable the bought space on SNAP wafer run

FCCD Project - History

- SNAP 6-inch wafer

Fast CCDs
30 μm pixels
480x480 metal strapped
350x380 metal strapped 4 port
480x558 non-strapped 4 port
20x480 metal-strapped

P. Denes

FCCD Project - Collaboration

- SPIE Conference in July 2005 (International Society for Optical Engineering)
  - Howard Padmore gave talk "Fast CCD-based systems for detection of x-rays and electronics" H.A Padmore, C.J.Bebek, M.Church, P.Denes, C.R.M.Greaves, S.E.Holland, H. von der Lippe, Lawrence Berkeley National Lab
  - Steve Ross attended talk and met with Howard after presentation
  - Discussed the possibility of collaborating with LBNL in the development and fabrication of x-ray detectors based on fast CCD chips and fast readout chips.
- 2005 Meetings with LBNL in October and December
  - LBNL has expertise in IC design
  - ANL has expertise in design and fabrication of CCD-based x-ray detectors, especially in the opto-mechanics and data acquisition
- Contacted beamline scientist and users to get input and verify interest
- Received APS approval to collaborate with LBNL to build FCCD Detector
  - (1 FTE and 100K)
- Build at least 2 of everything so each lab would have their own Detector

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FCCD Project – Custom ICs

- **Fast CCD**
  - 480 x 480 (30um pixels)
  - Back-illuminated CCD
    - *Good quantum efficiency (QE) for phosphor coupled x-ray cameras*
  - Thick substrate of 200-300 um (Fully Depleted)
    - *Direct detection of X-Rays*
  - Added Almost Column-Parallel Readout
    - *Split Top and Bottom of CCD and have one output for 10 columns*
    - *Readout time of 2.4 msec / frame = max of 416 frames/sec*
    - *192 Mbytes/sec*
- **Custom Readout IC to perform ADC on 96 analog outputs**
  - 16 Analog Inputs – 14bit outputs
  - Conversion Rate of 1usec/pixel
  - 4 Serial LVDS output
- **Both CCD and Readout IC are based on SNAP design**

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FCCD Project – Almost Column-Parallel Readout
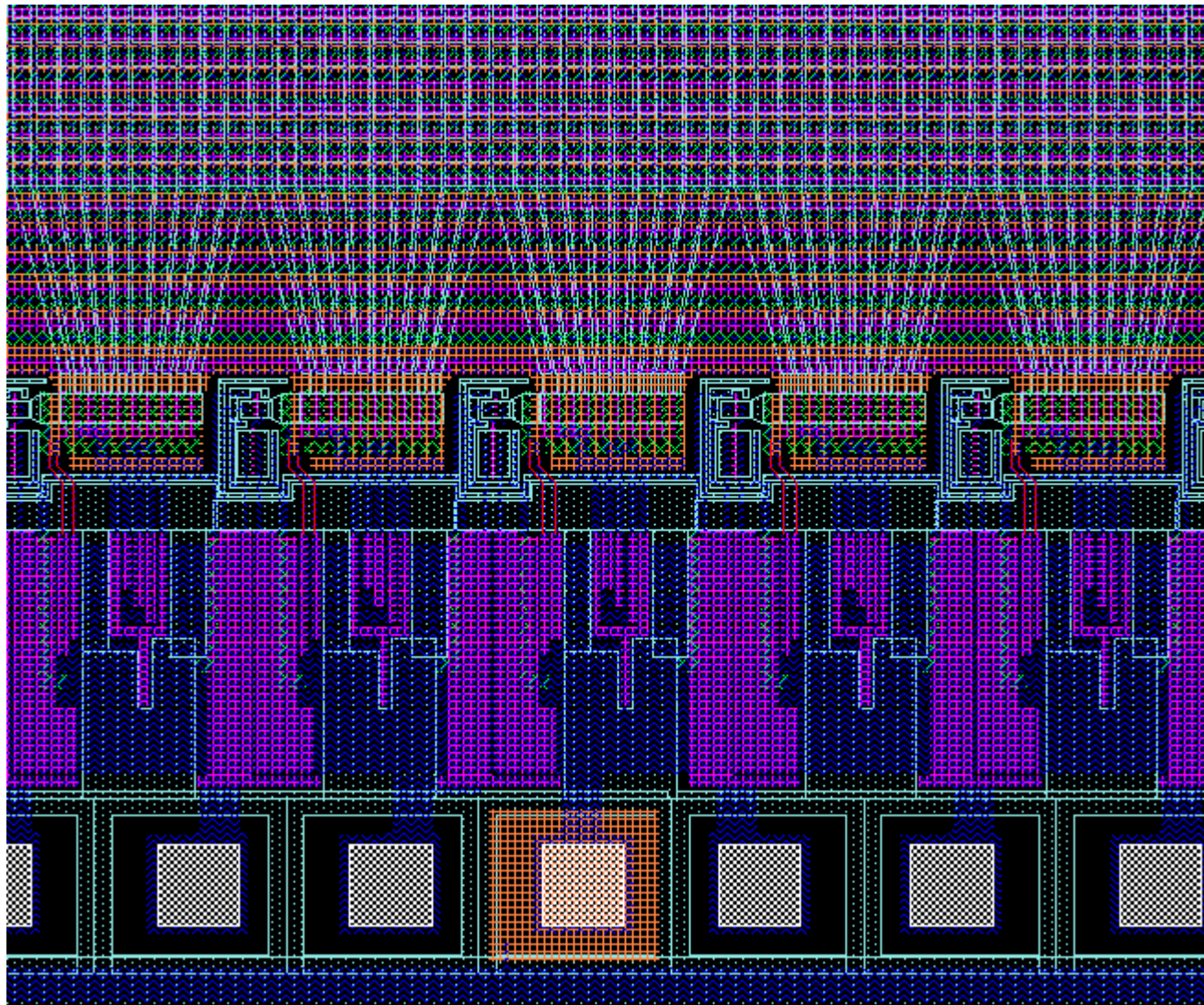
P. Denes

FCCD Project - Block Diagram

Front End Electronics

Back End Electronics

Each FRIC has 1 SPI-Like I/O bus and 4 LVDS output streams

LBNL

APS

FCCD

Analog Outputs

DAS Electronics

CCD

480 x 480

10 columns per analog out

½ row per output

fCRIC 1
16

fCRIC 2
16

fCRIC 3
16

fCRIC 4
16

fCRIC 5
16

fCRIC 6
16

Data Module 1

Interface to 3 FRICs

Data Module 2

Interface to 3 FRICs

Clock Module

Interface Module

Camera Link

Power Supplies

Interlock and Temperature Controller
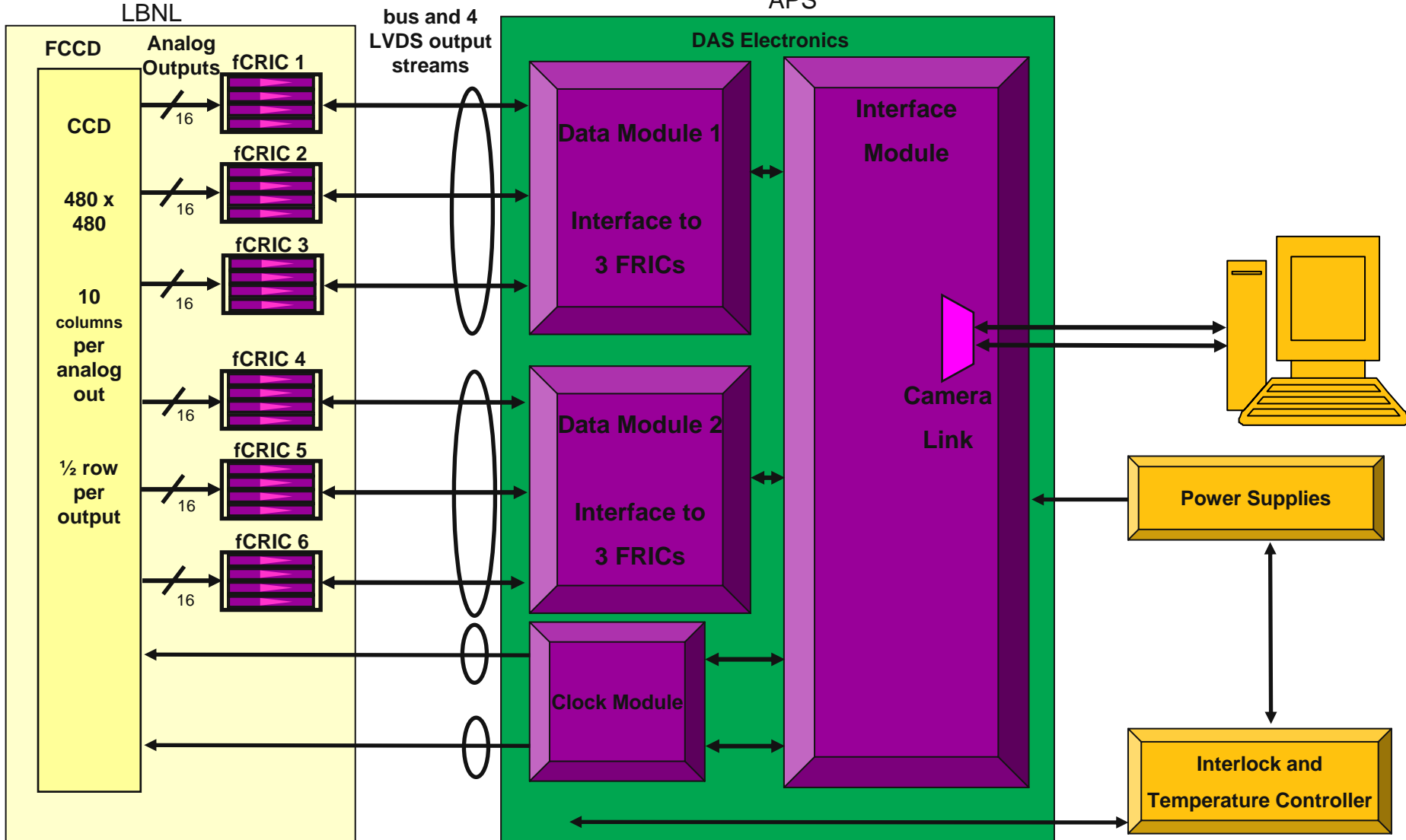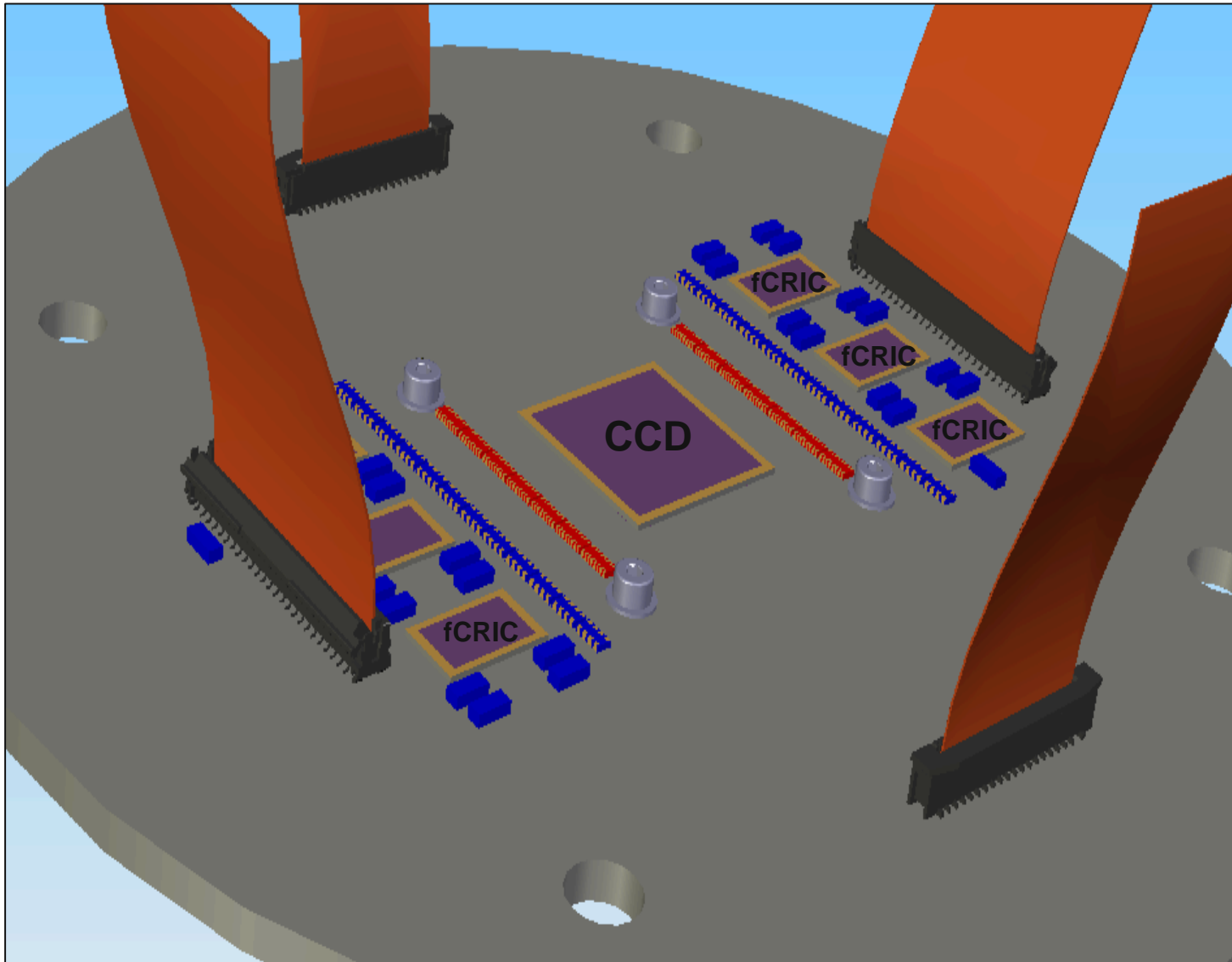
M. Church

FCCD Project - Assembly
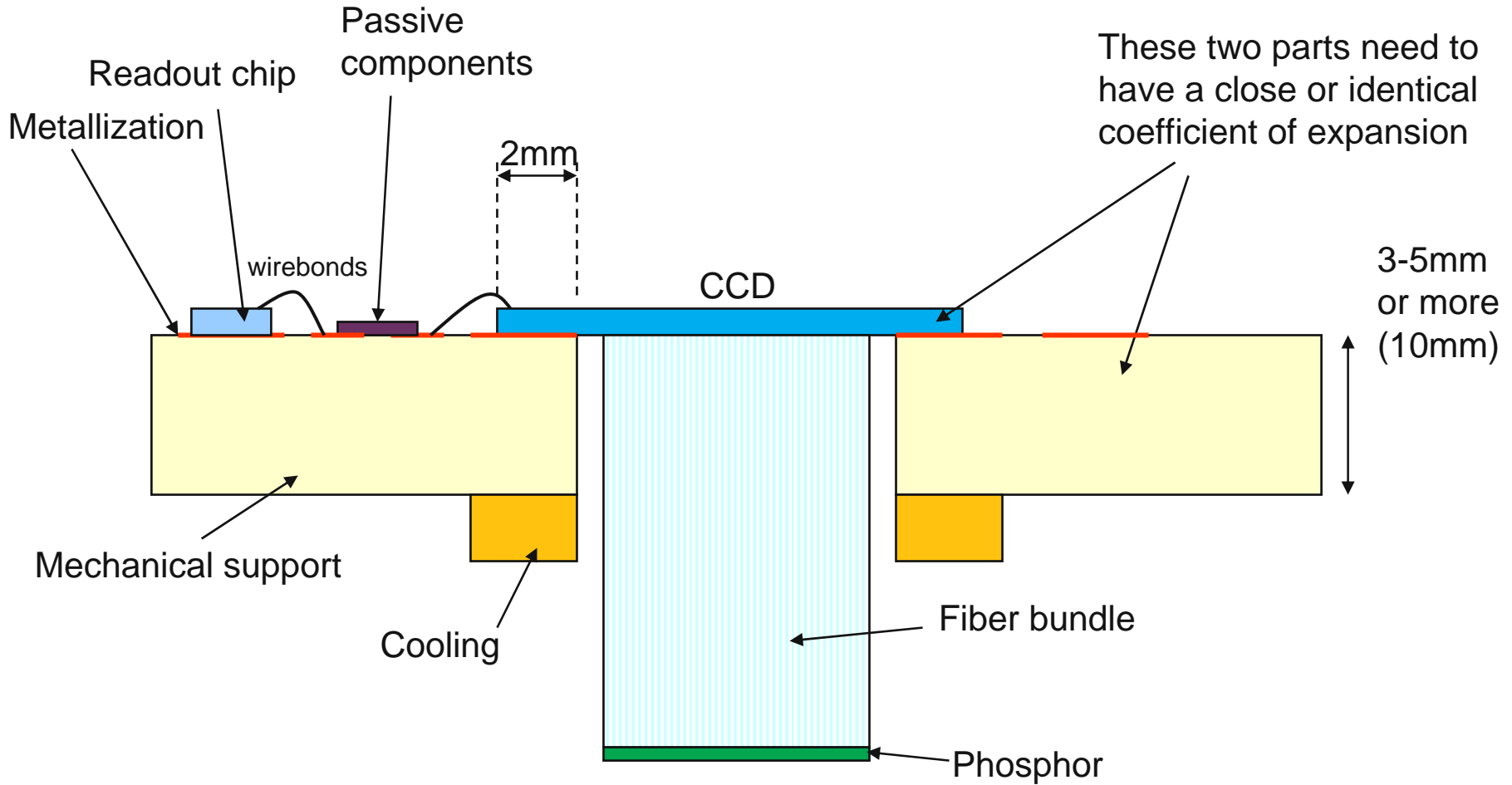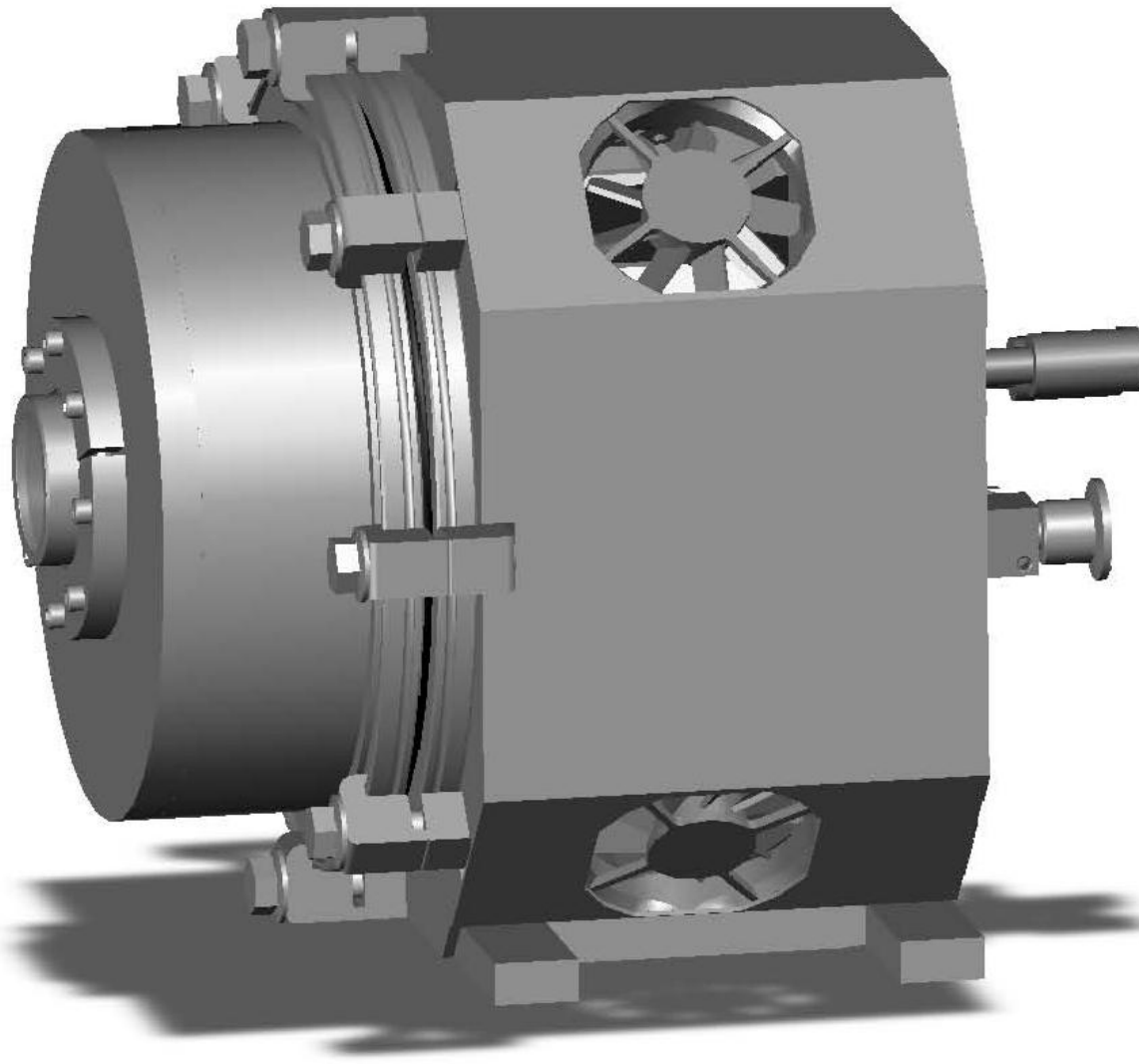
Passive components

Readout chip

Metallization

These two parts need to have a close or identical coefficient of expansion

2mm

wirebonds

CCD

3-5mm or more (10mm)

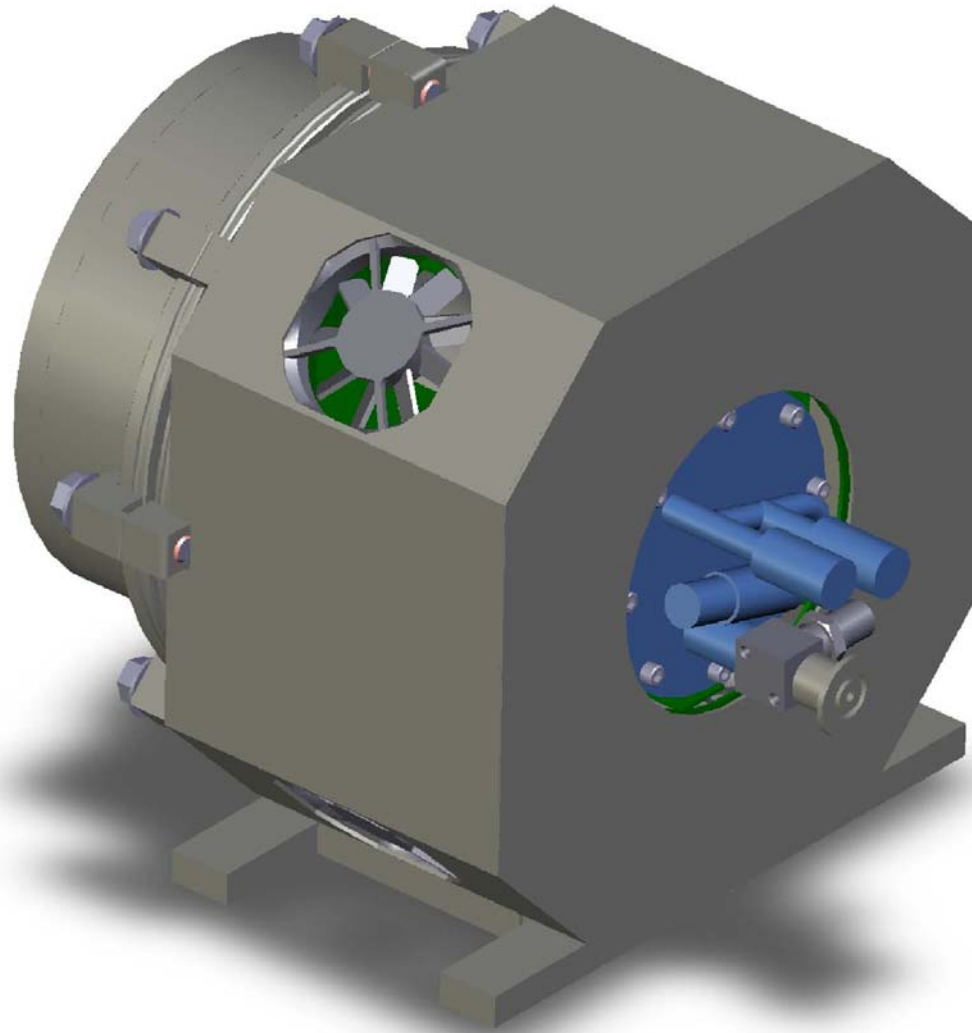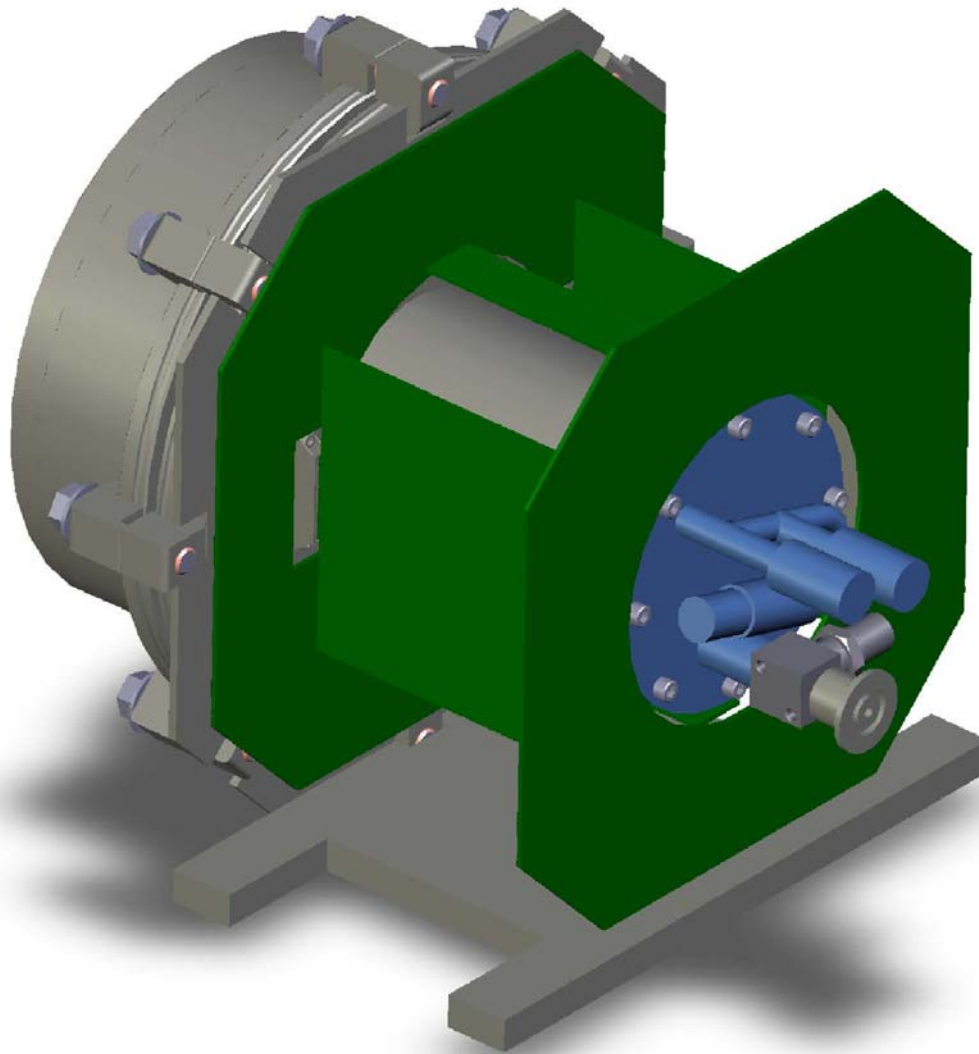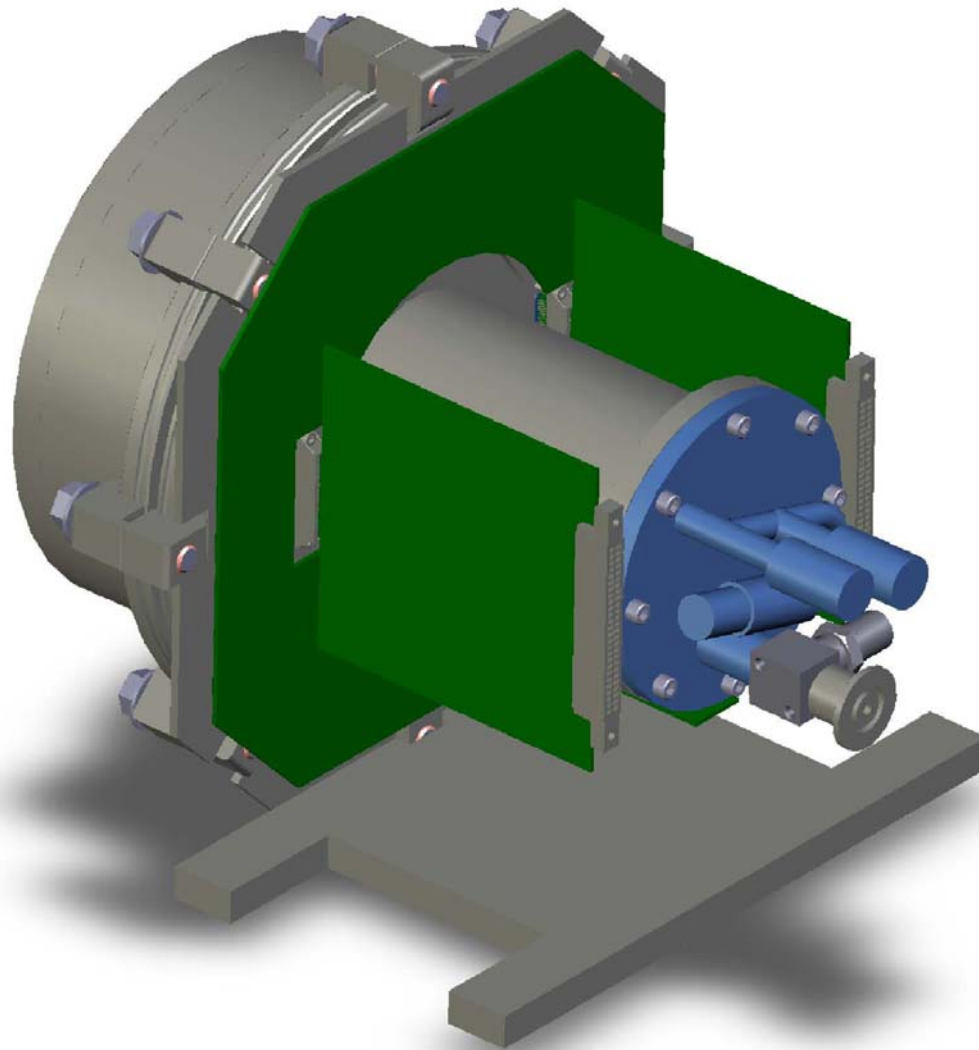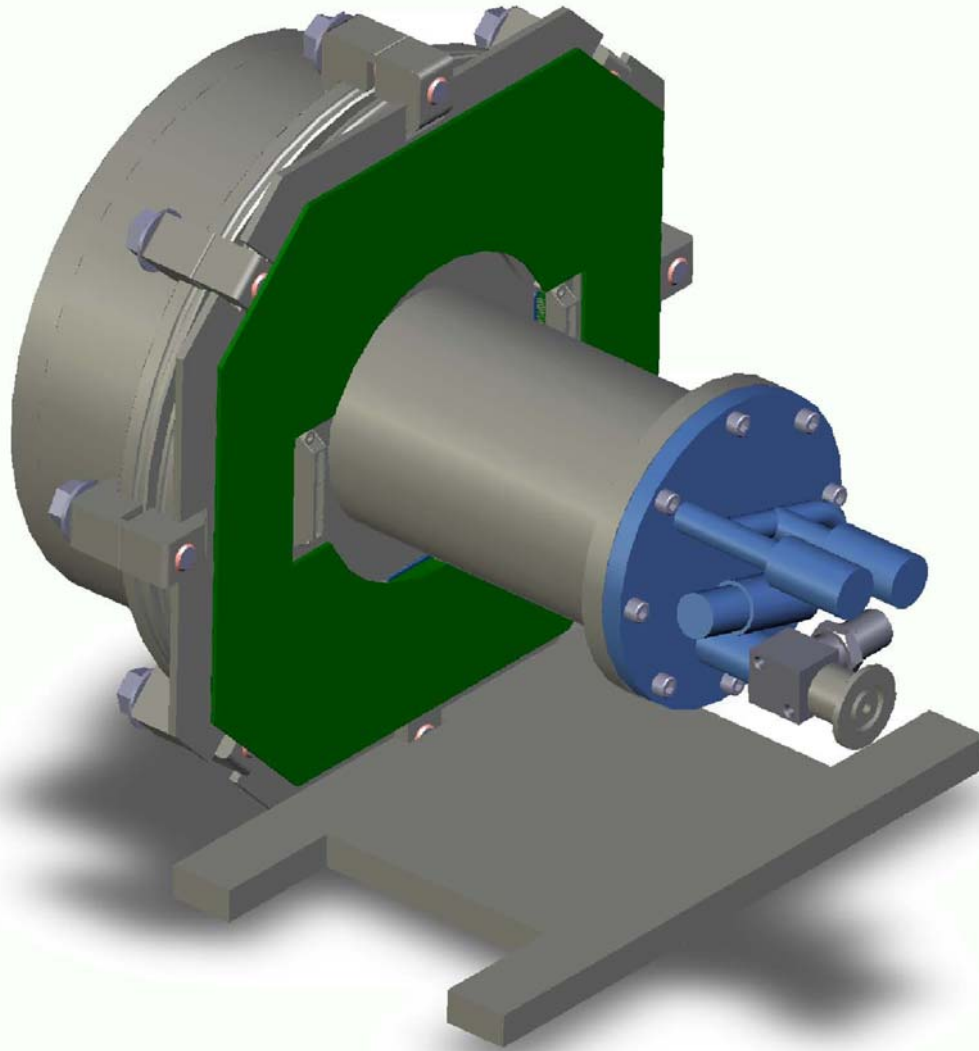Mechanical support

Cooling

Fiber bundle

Phosphor

Fast CCD Project – Mechanical Drawing

M. Church

Fast CCD Project – Mechanical Drawing

M. Church

Fast CCD Project – Mechanical Drawing

M. Church
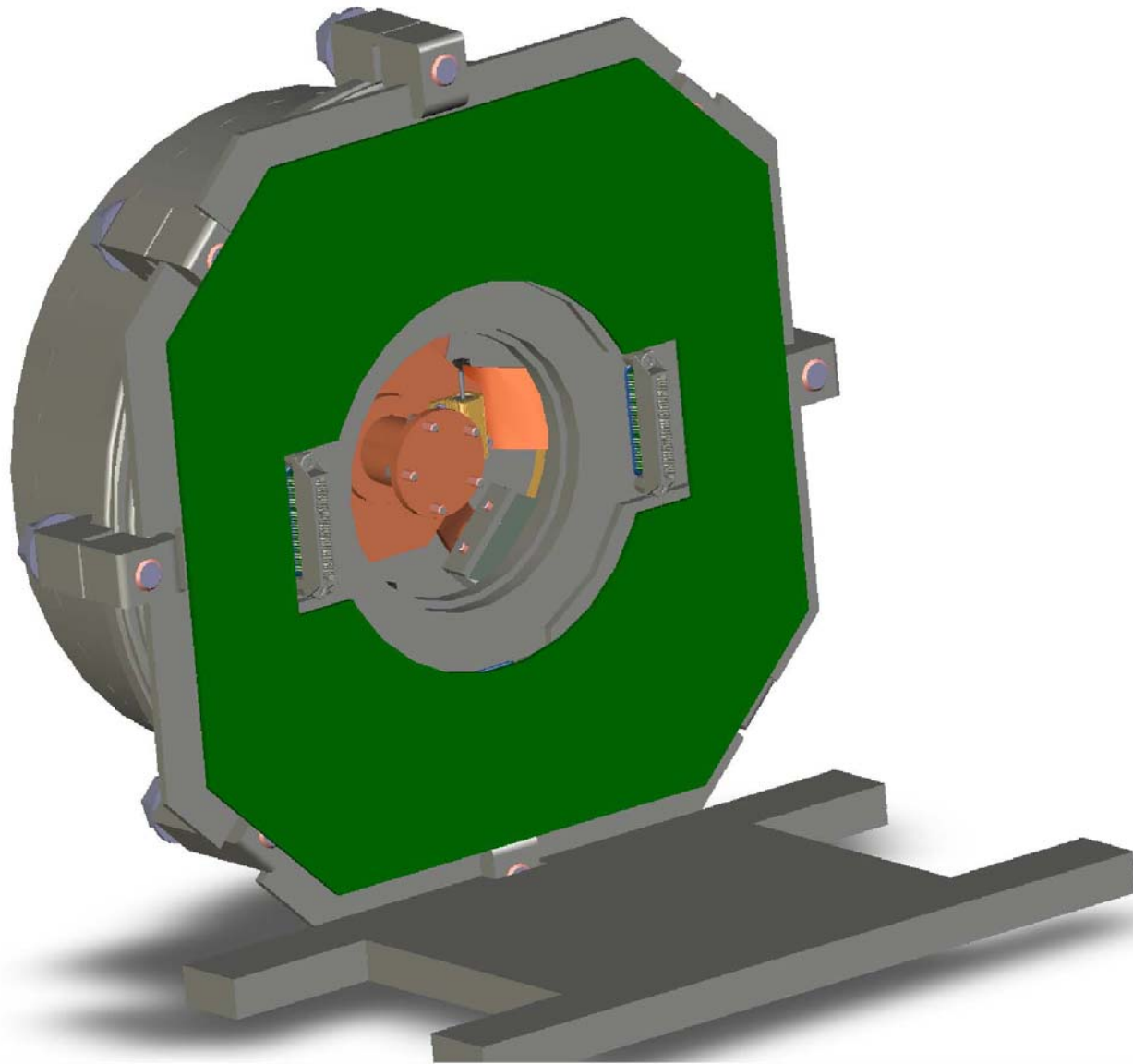
M. Church

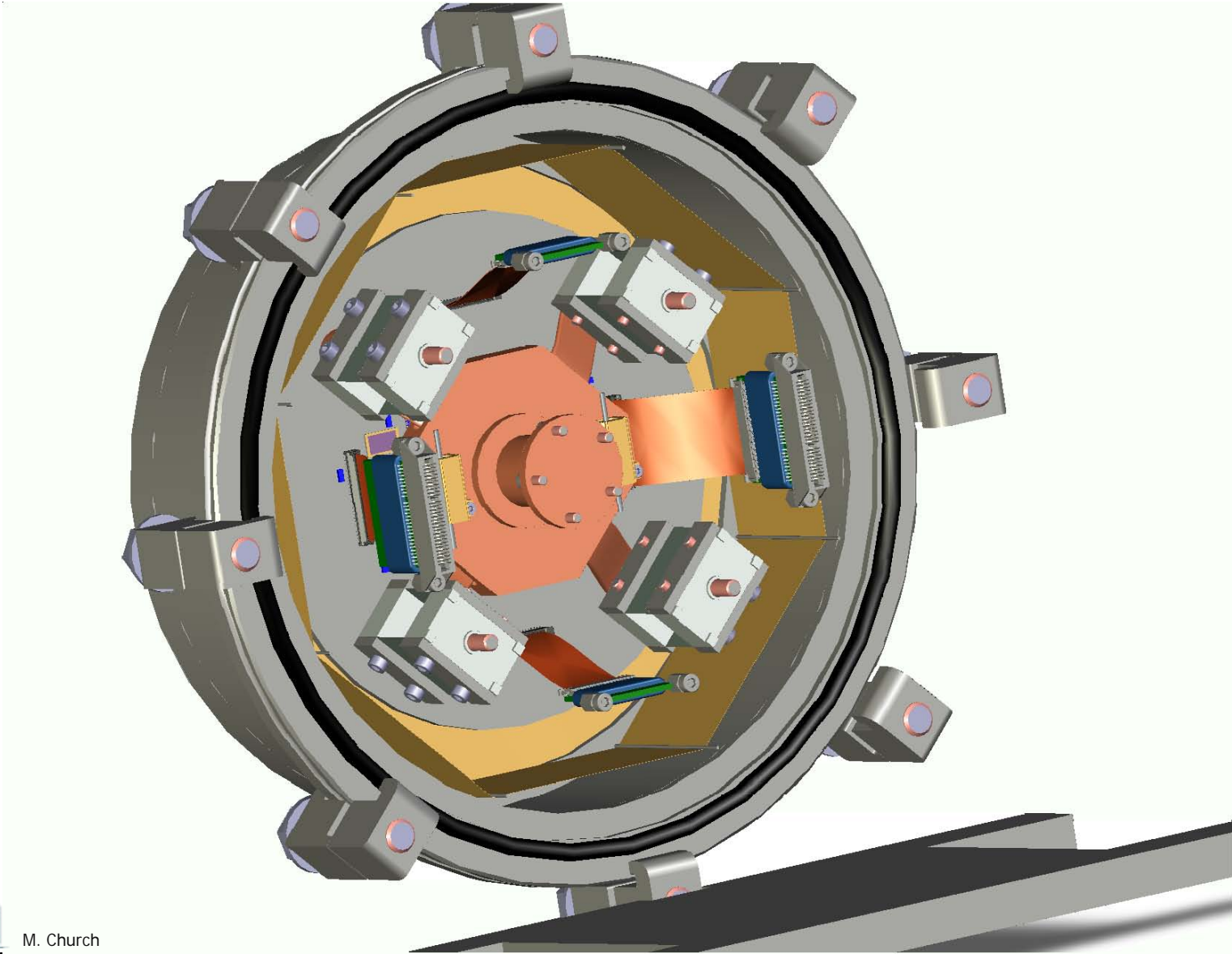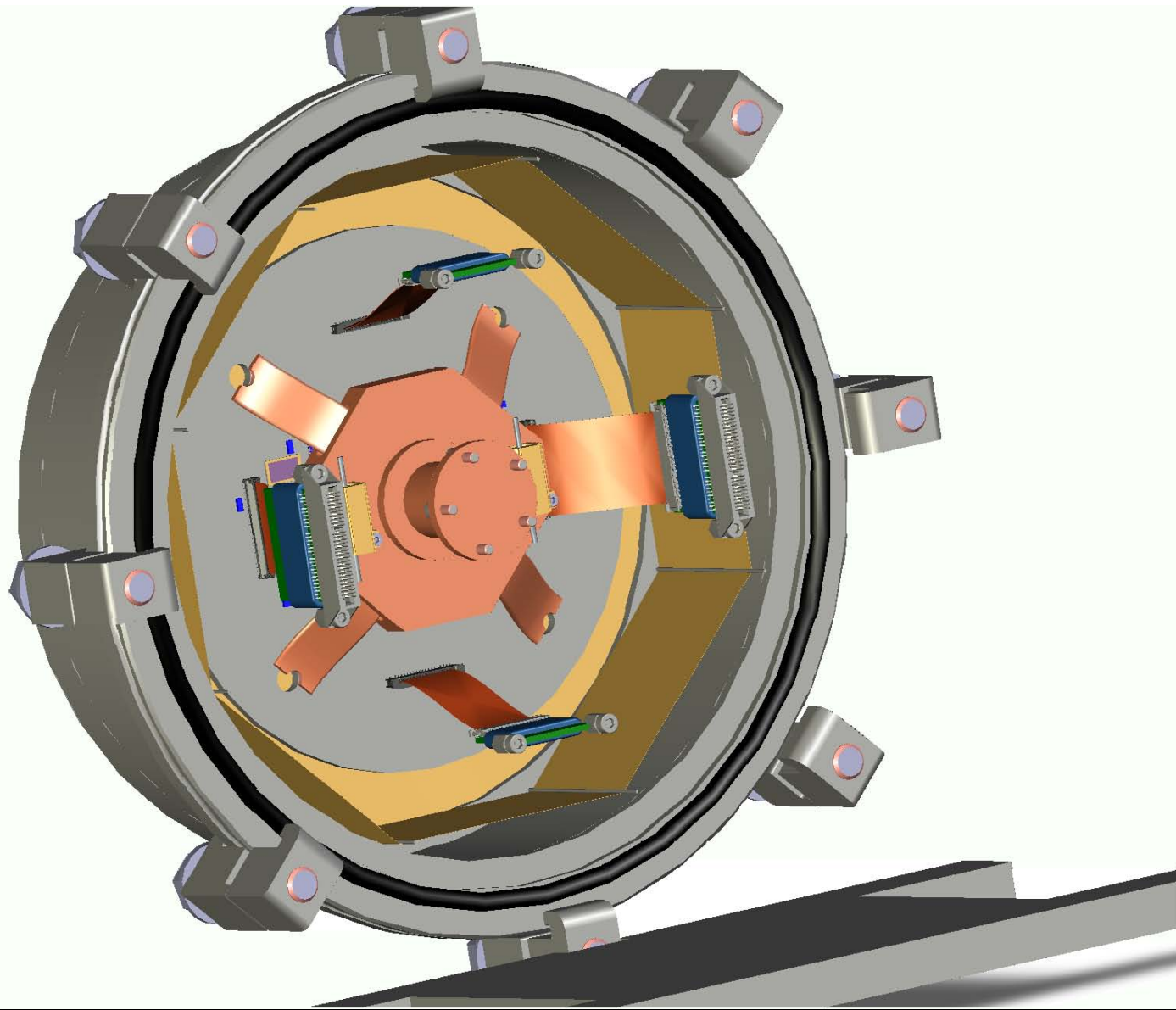# *Fast CCD Project – Mechanical Drawing*

M. Church

Fast CCD Project – Mechanical Drawing

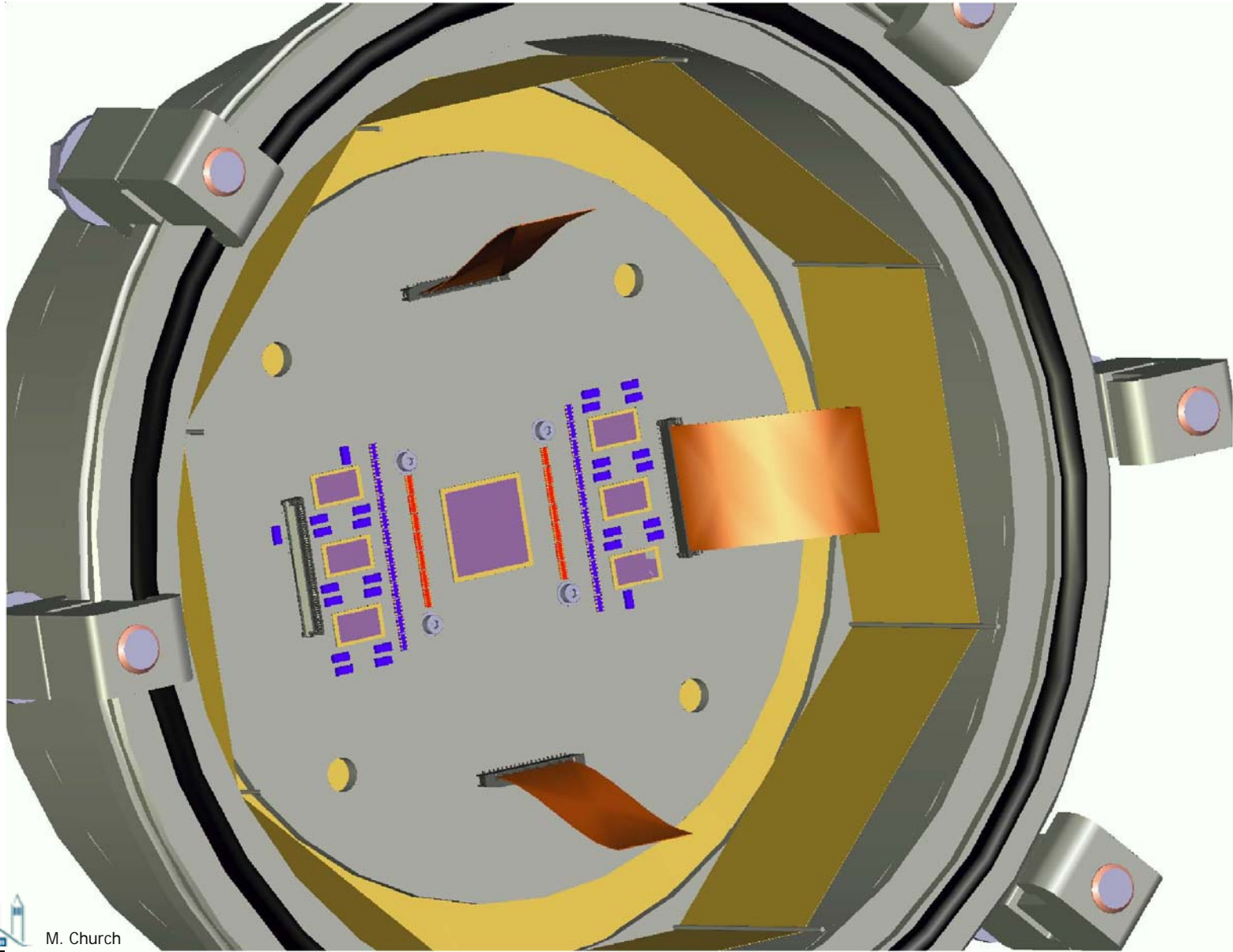M. Church

Fast CCD Project – Mechanical Drawing

M. Church

Fast CCD Project – Mechanical Drawing

M. Church

Fast CCD Project – Mechanical Drawing

M. Church

M. Church

FCCD Project - Status

- LBNL
  - Expect FCCD from DALSA in mid November
    - *Disadvantage of sharing wafer run - SNAP problems are your problems*
  - Received FCCD Readout Chip (fCRIC)
  - Initial testing of fCRIC looks good
  - Started putting together mechanical mockup of CCD assembly
  - Have FCCD vacuum chamber in house
- APS
  - Two of three schematics done - ready to make into PCBs
  - Started Altera FPGA Code related to fCRIC interface
  - Have two Coreco frame grabbers for data acquisition
- LBNL and APS
  - Numerous video conferences and visits to each other's lab
  - Matthew Church and James Glossinger visit – observed Tim Madden and John Lee assemble and test the vacuum housing for the BESSRC Project. (Model for larger FCCD camera)

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FCCD Project – Future

- LBNL
  - Test fCRIC (Dec 2006)
  - Initial testing of FCCD
  - Test vacuum housing with CryoTiger cooling system
  - Finish mock up assembly with CCD and fCRICs on Si wafer
  - Build final assembly
- APS
  - Assemble circuit boards (Jan 2007)
  - Program Altera FPGAs (Firmware)
  - Develop Software
    - *Use code developed by Brian Tieman and the BCDA Group*
    - *Code specific to FCCD*
- LBNL & APS
  - Integrate LBNL assembly with ANL electronics (March 2007)
  - Finish testing and characterizing the FCCD
  - Test at beamlines

Future Projects

- **FCCD Project is a stepping stone to bigger and better detectors**
  - Design Larger FCCD 1k x 1k or 2k x 2k
  - Build large X-ray detector with mosaic of larger FCCDs
  - Increase speed
    - *More columns*
    - *Faster ADCs*