ALMA-
Band 9 and Band 5
Technology

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NOVA / Kapteyn Institute / University Groningen

Partners

Customer:

ESO/ALMA

Band 9: finished end 2011

- NOVA + TU-Delft

Band 5: 2013-2017

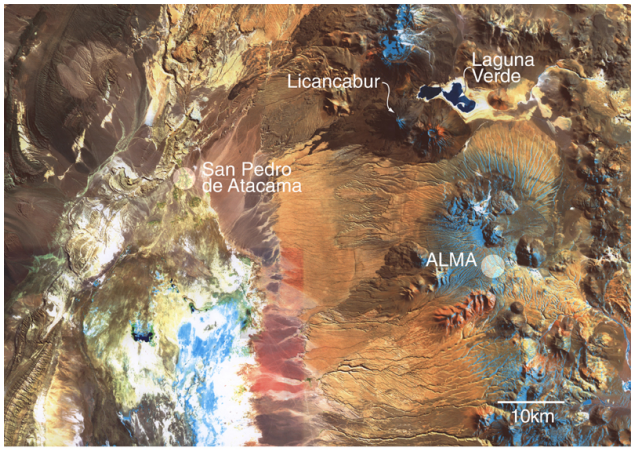
- GARD (University Goteborg, Sweden) + NOVA

Examples how to develop an ALMA receiver with:

- high quality receiver
- easy to assemble and maintain
- Cost effective

Location

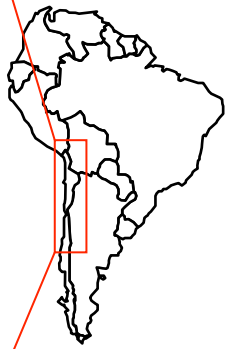
500 km

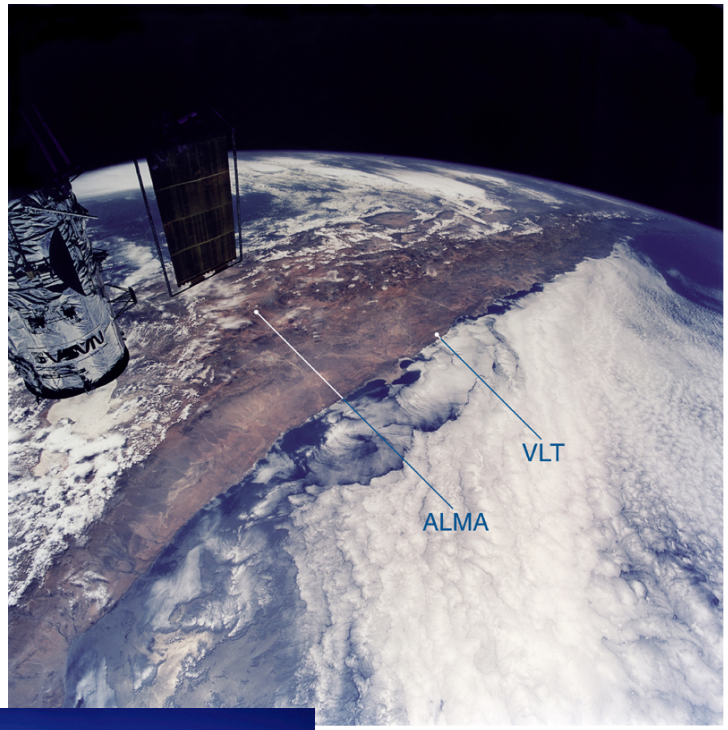


Location of the Compact Configuration of ALMA

ESO PR Photo 24c/99 (8 June 1999)

© ESO/Cornell University





Chile (NASA Space Shuttle)

© ESO - ESA - Claude Nicollier

Panoramic View of the Proposed Site for ALMA at Chajnantor

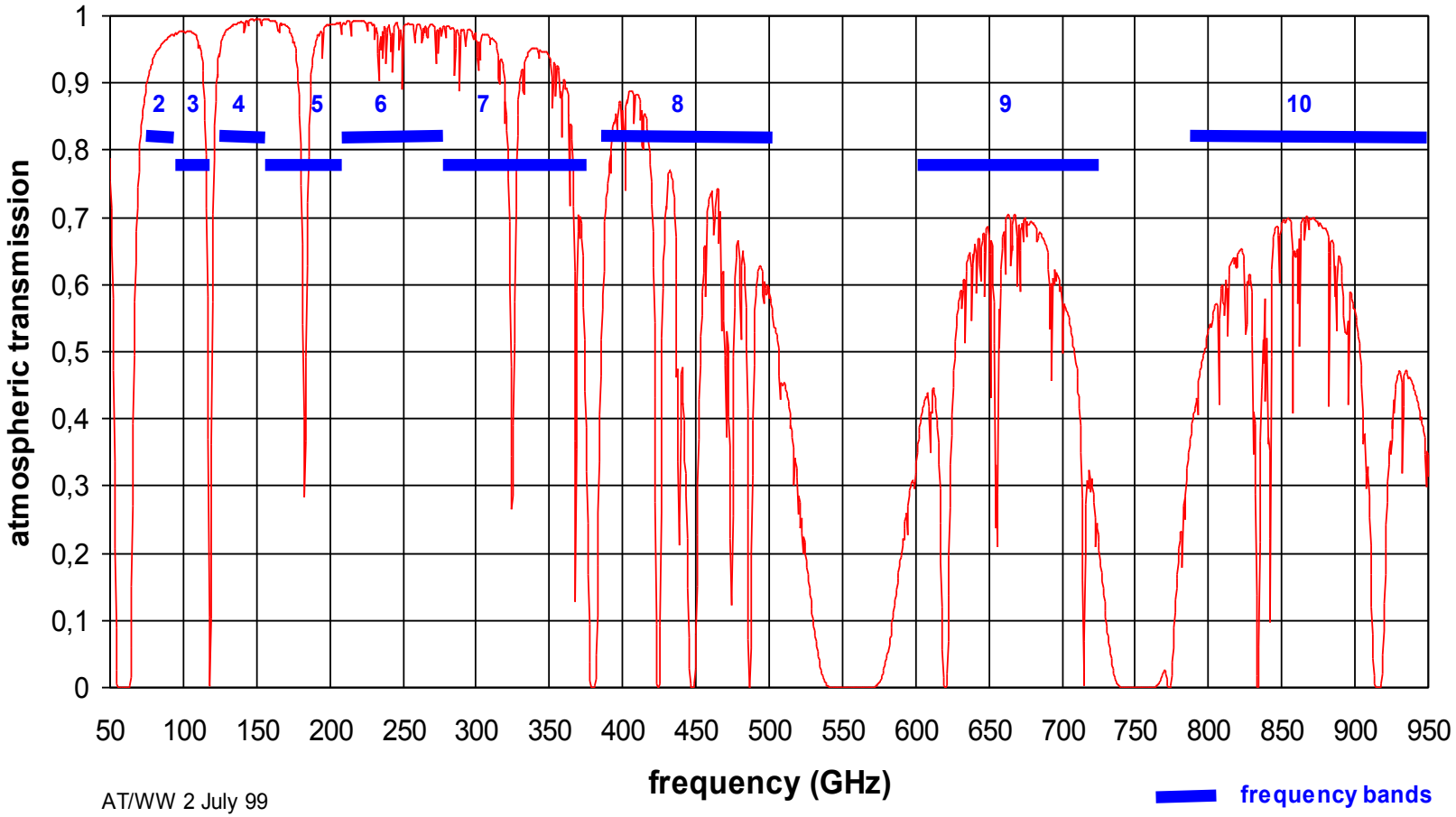
ESO PR Photo 24c/99 (8 June 1999)

© European Southern Observatory

Main Receiver Characteristics

- 10 observing bands (2 polarizations) in one dewar
- Highest possible reliability: avoid moving parts
- Modular design
- Easy to repair/maintain at OSF in Chili

ALMA Frequency Coverage

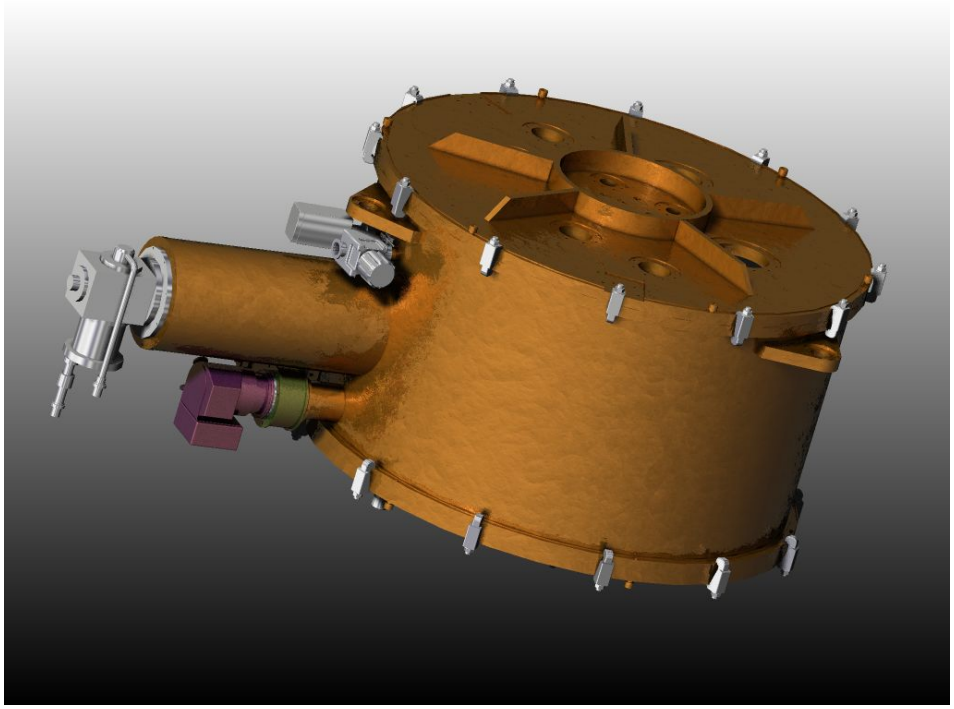


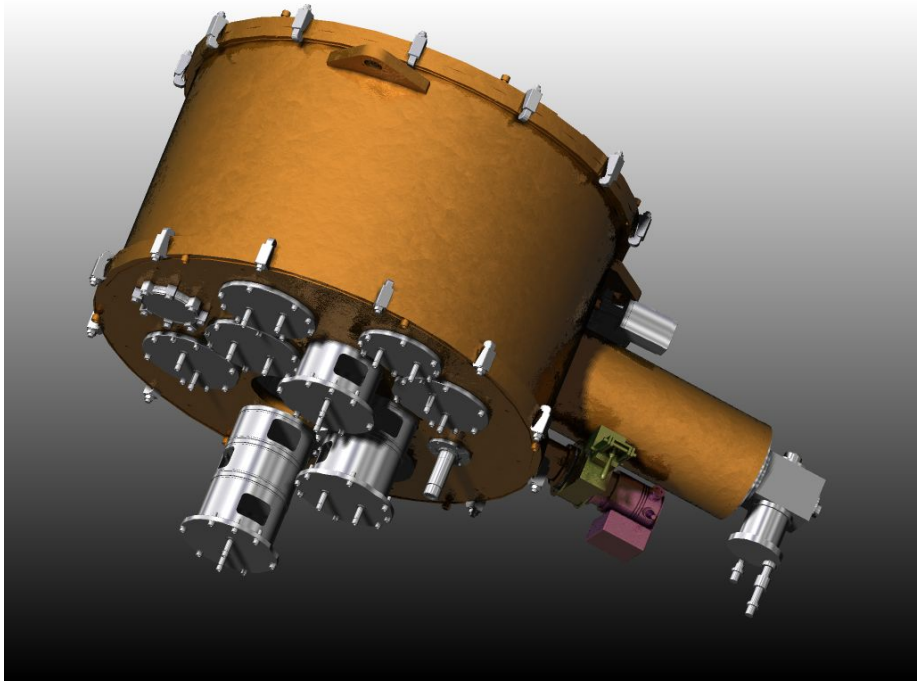
10 Bands

Band	Range [GHz]	Country		Band	Range [GHz]	Country
1	31-45	?		6	211-275	USA
2	67-90	?		7	275-373	France
3	84-116	Canada		8	385-500	Japan
4	125-163	Japan		**9**	**602-720**	**Netherlands**
5	**163-211**	**Neth./Sweden**		10	787-950	Japan

4 different Telescopes

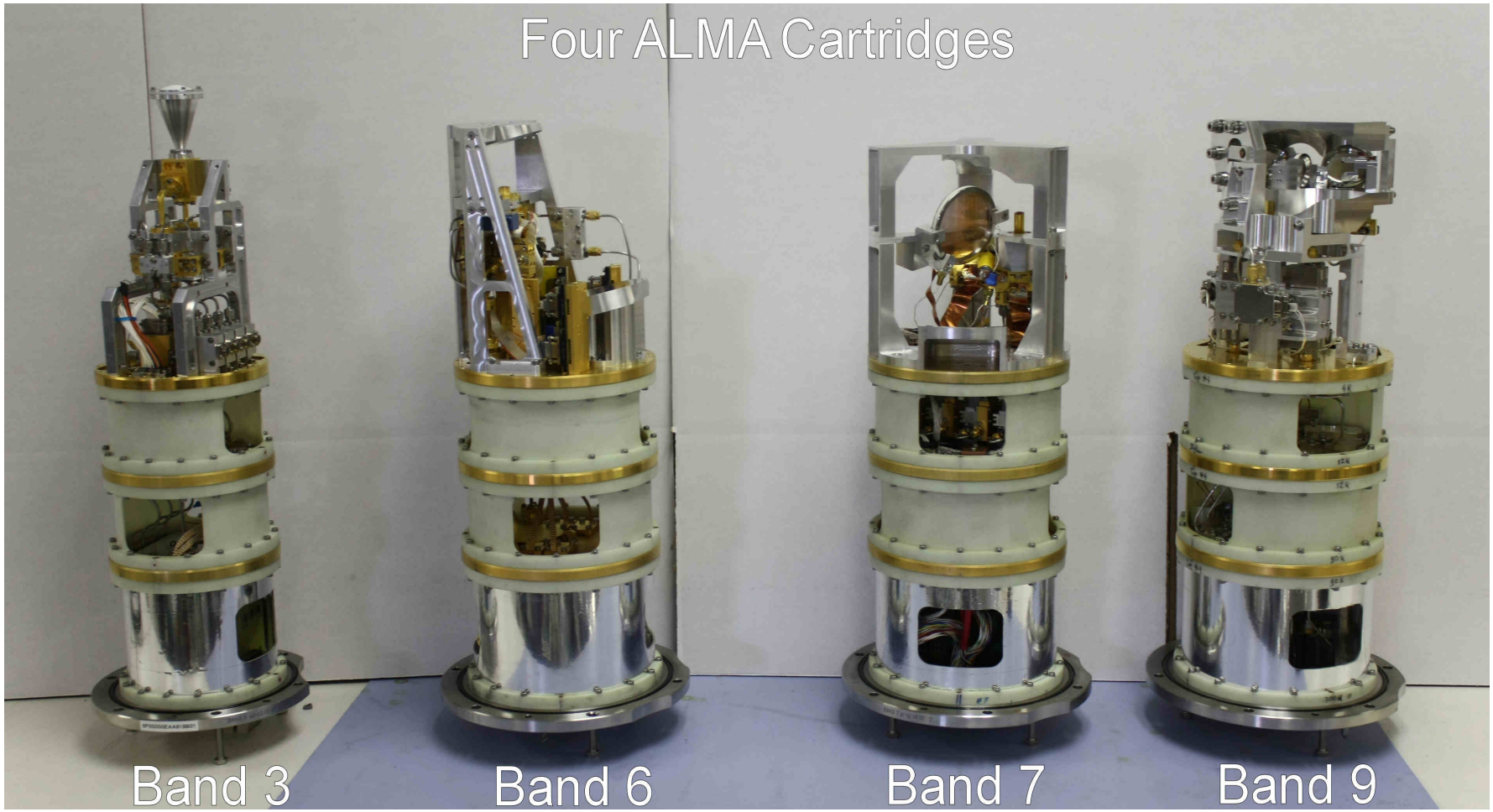
Cryostat behind each telescope



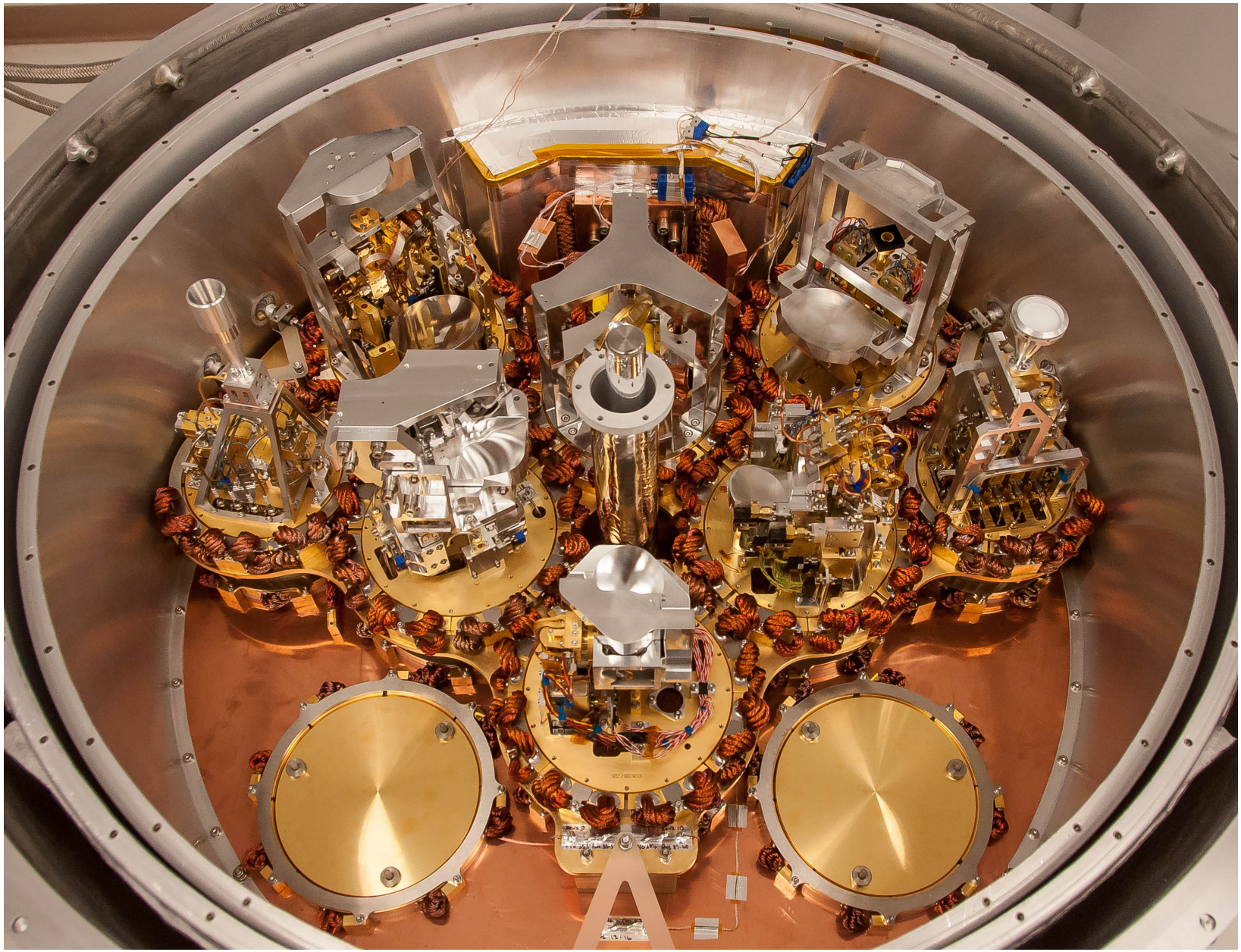


- 1 m diameter, ~ 65 cm height
- Space for 10 “cartridges” (one for each frequency band)
- cooling to 4 K, 12 K and 90 K

Baseline receivers



Cryostat with bands 3 to 10



Insert Cryostat behind Antenna

Development example 1: Band 9 Optics

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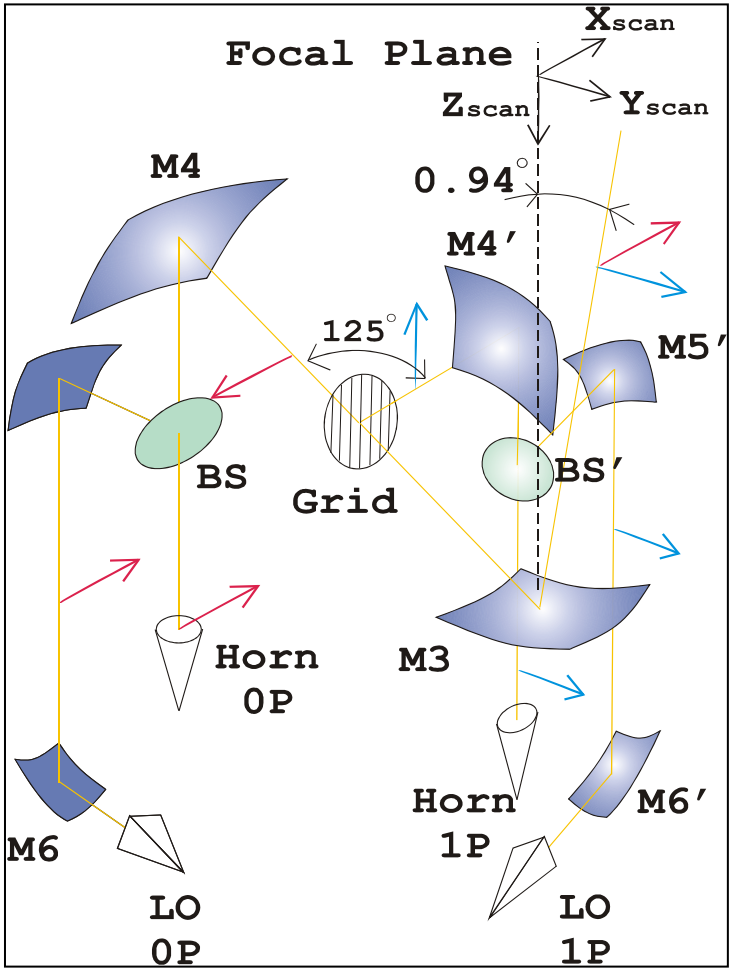
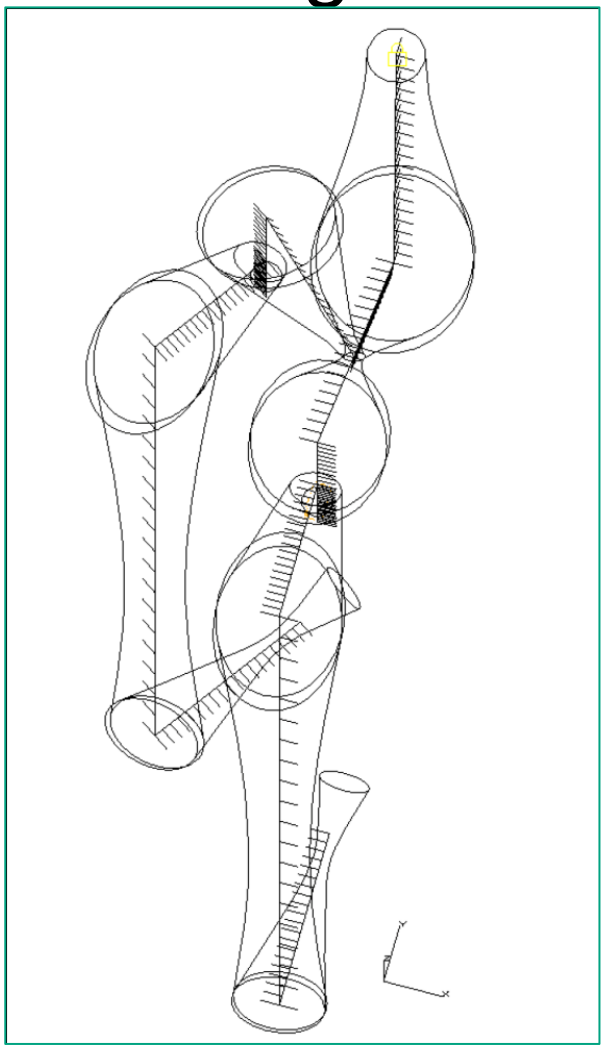
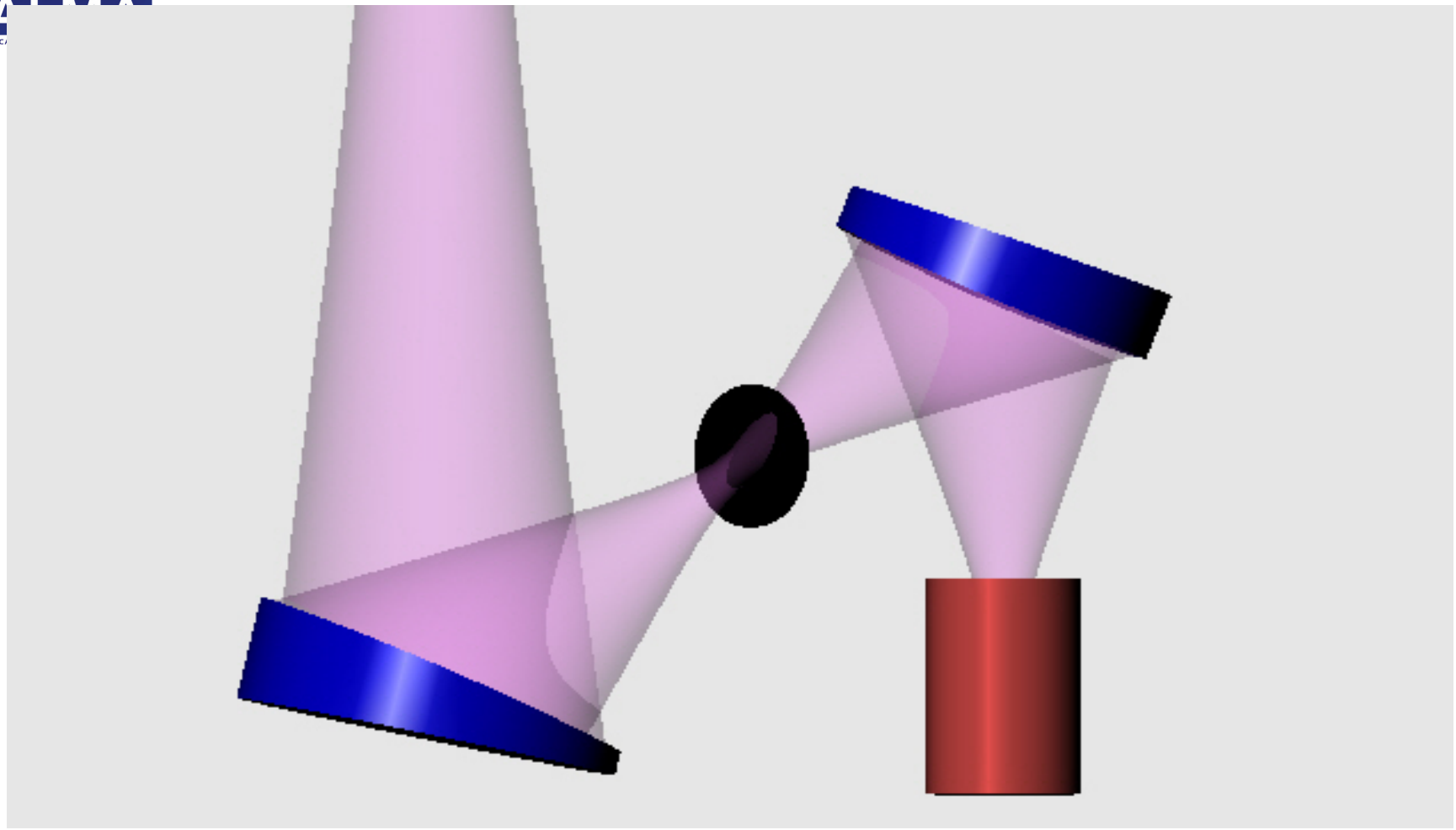
Start: Optical Design

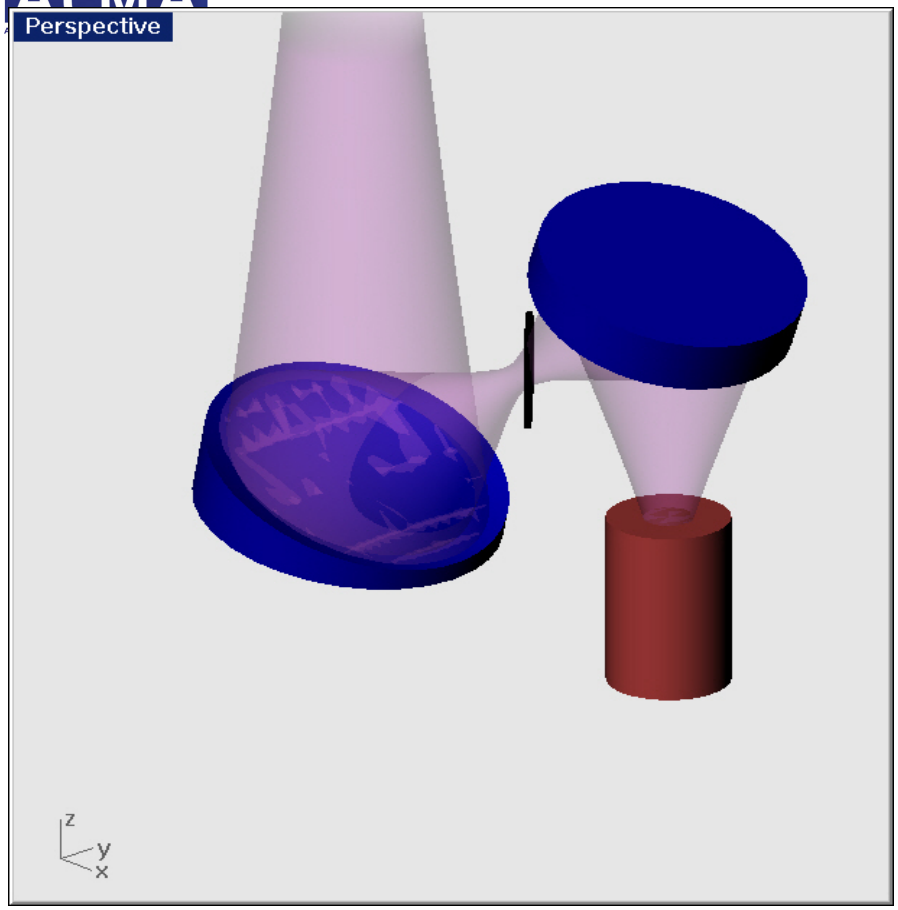


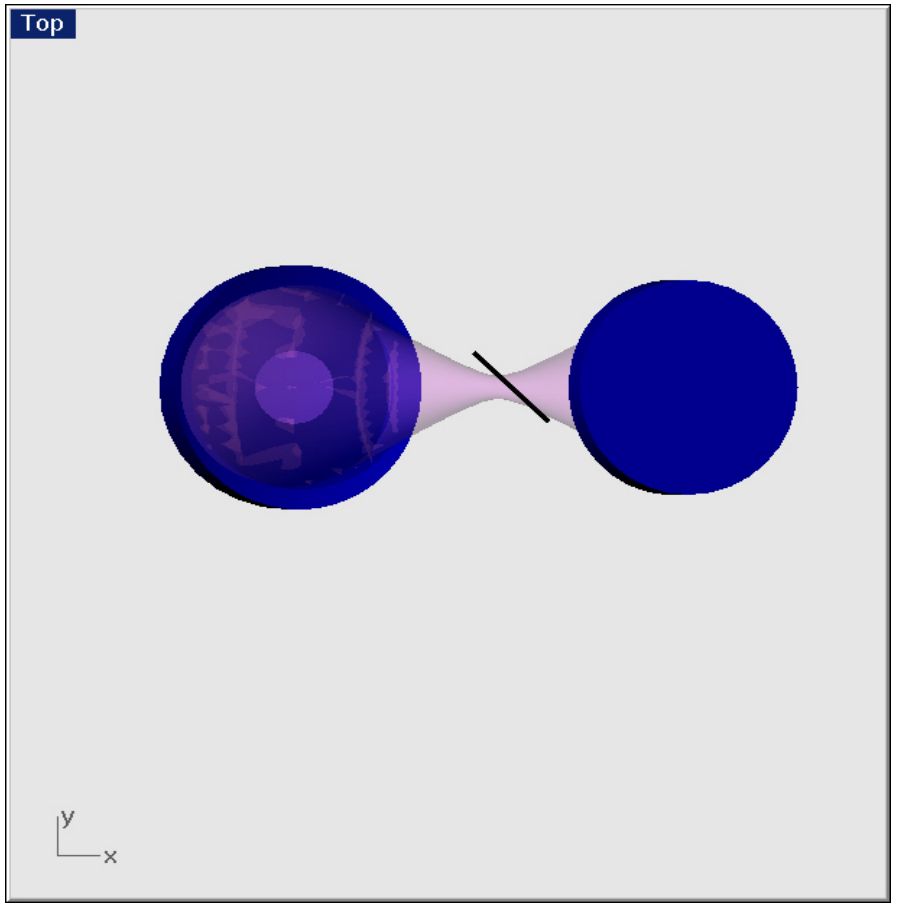


Signal beam in 3D

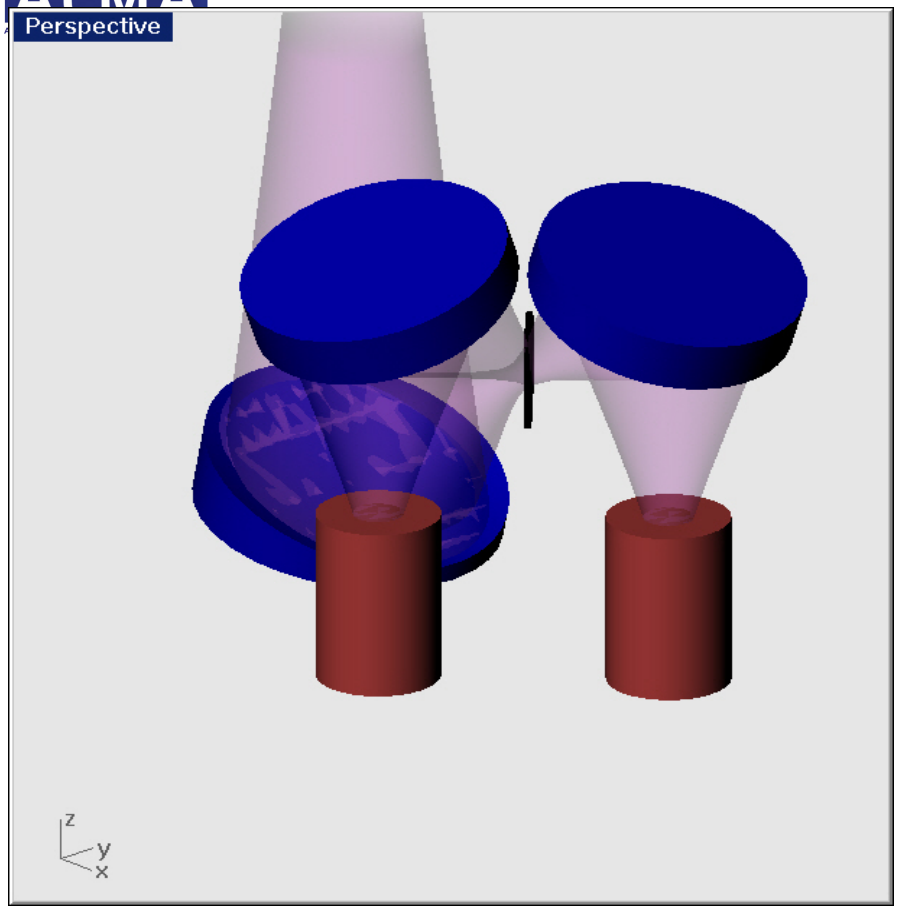


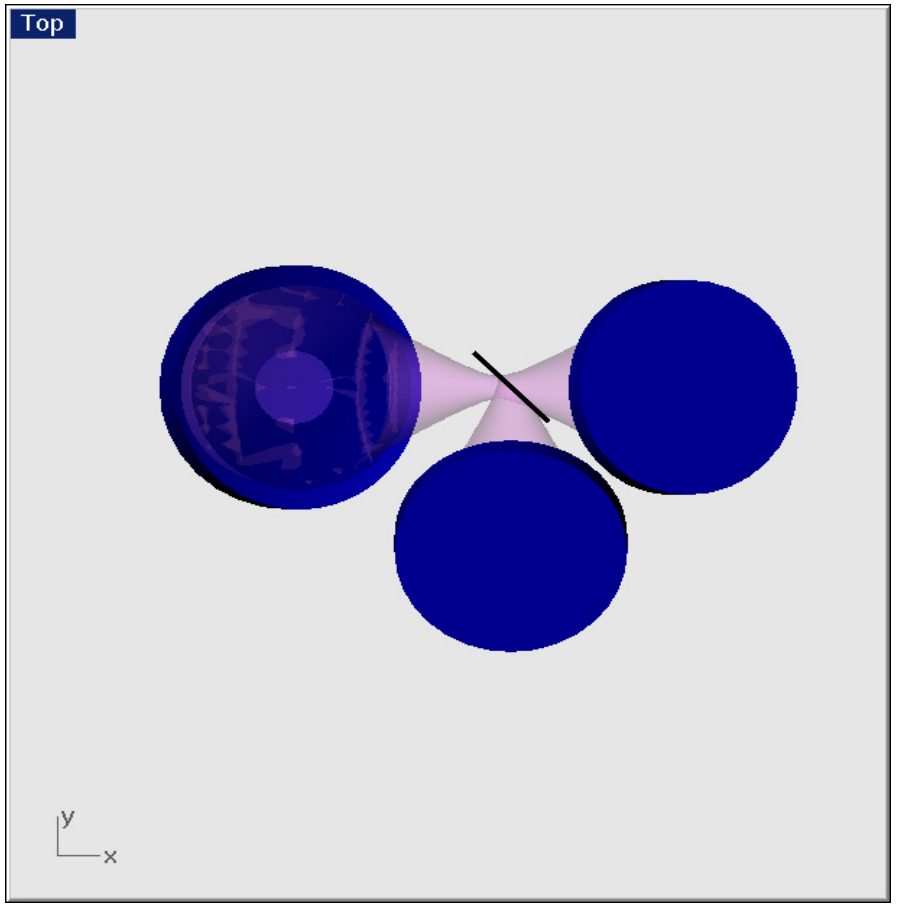
Assemble I



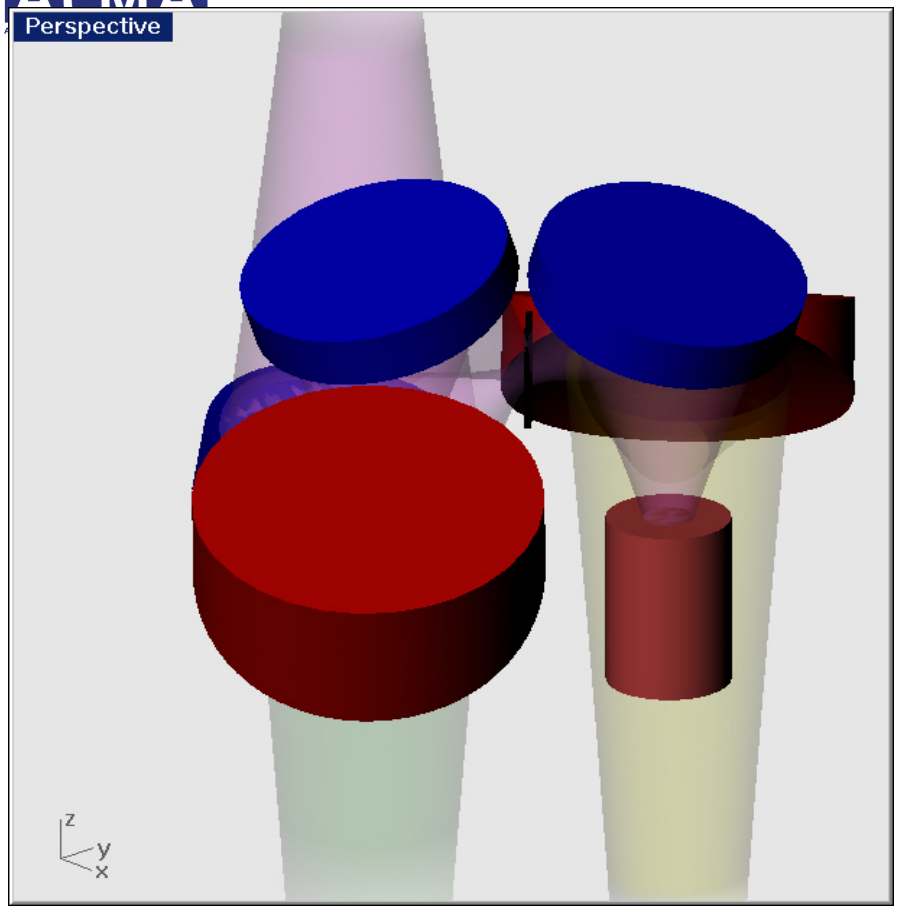


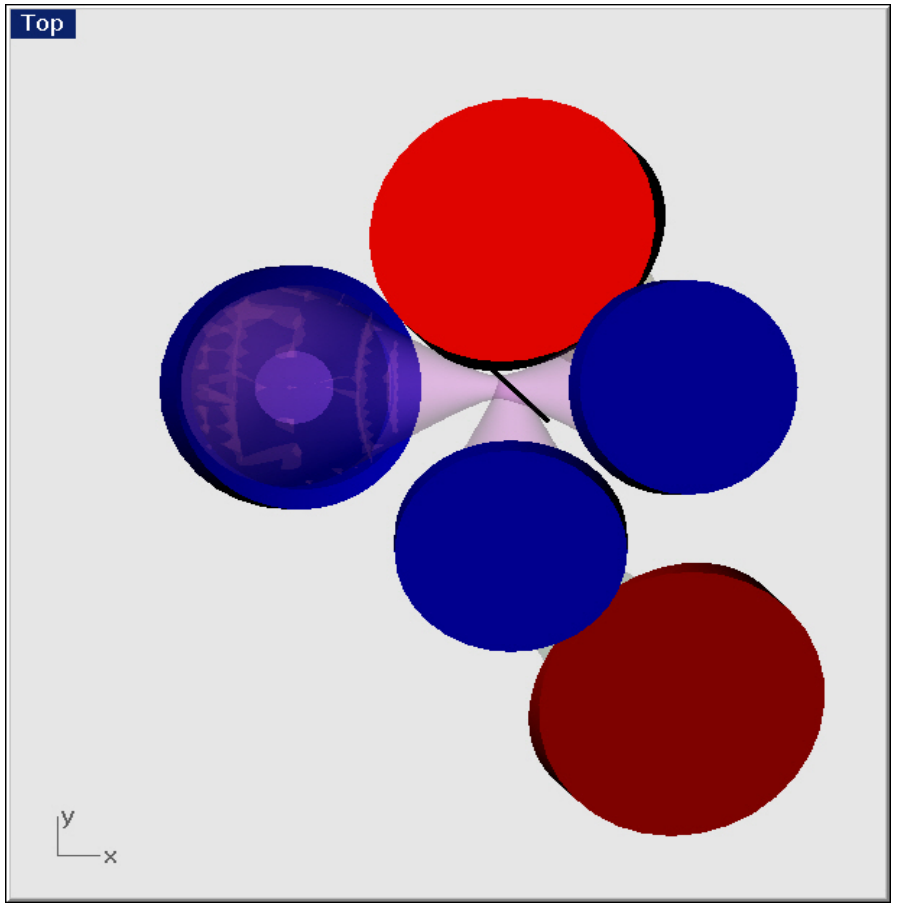
Assemble II



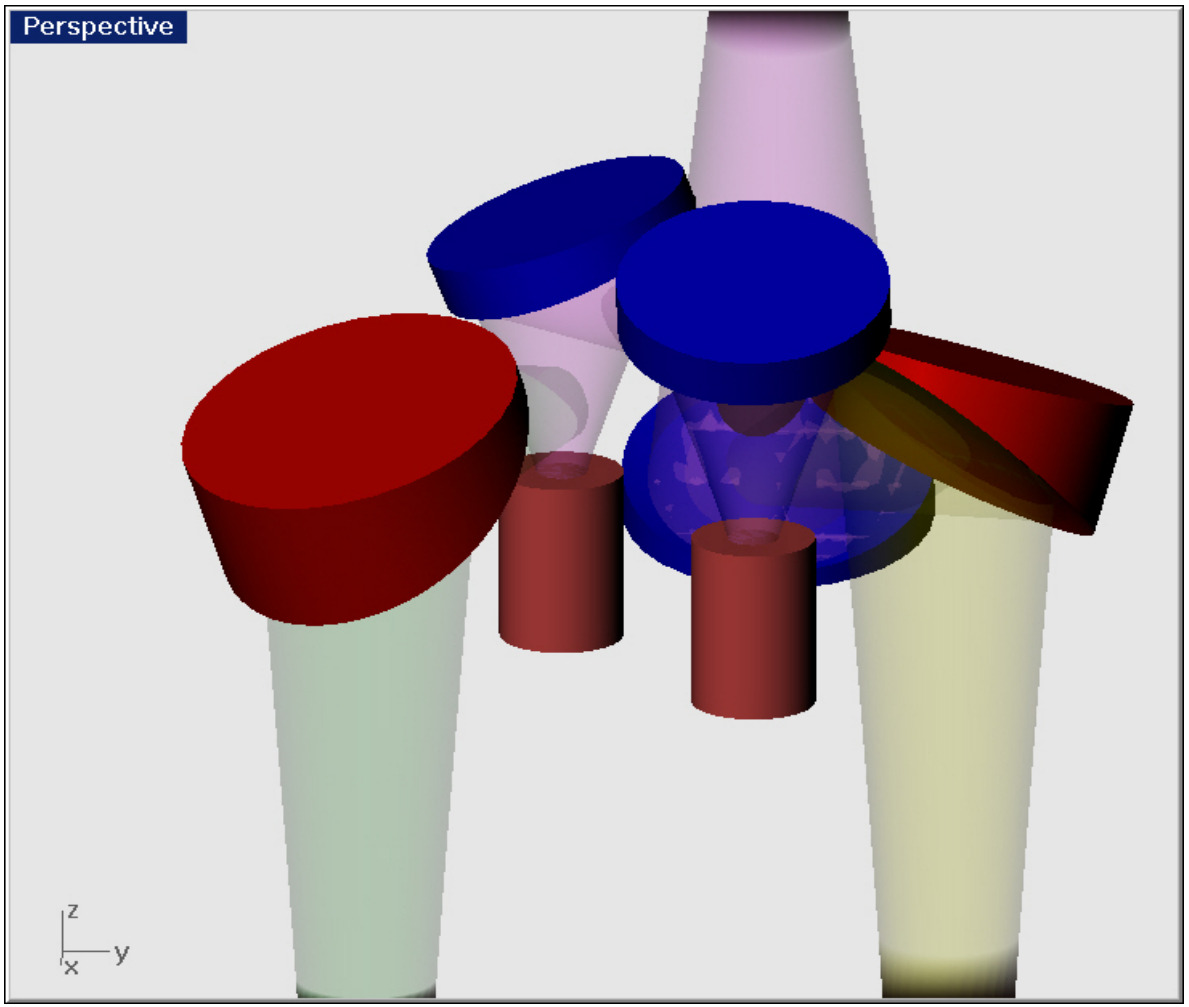


Assemble III

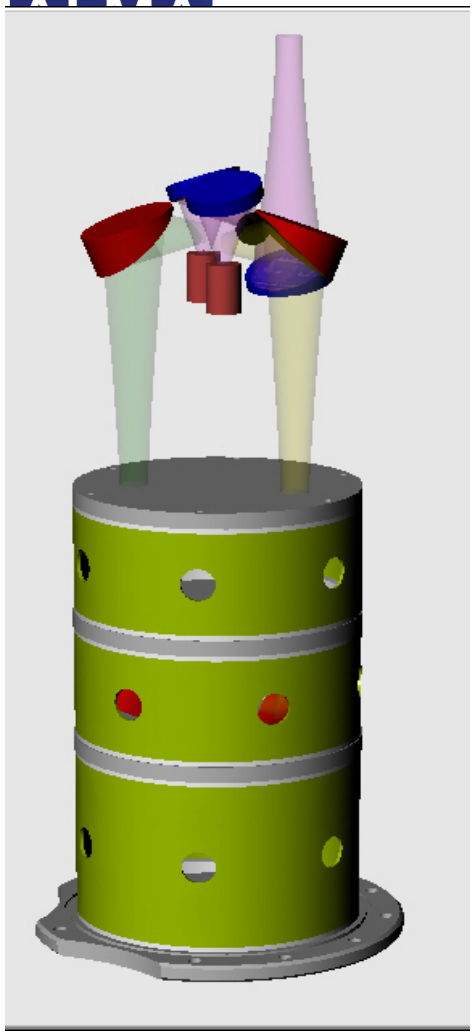


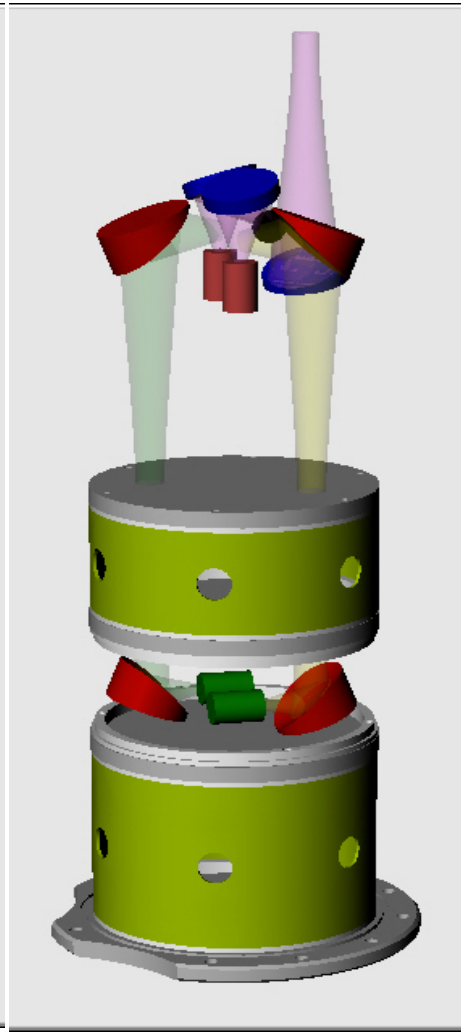


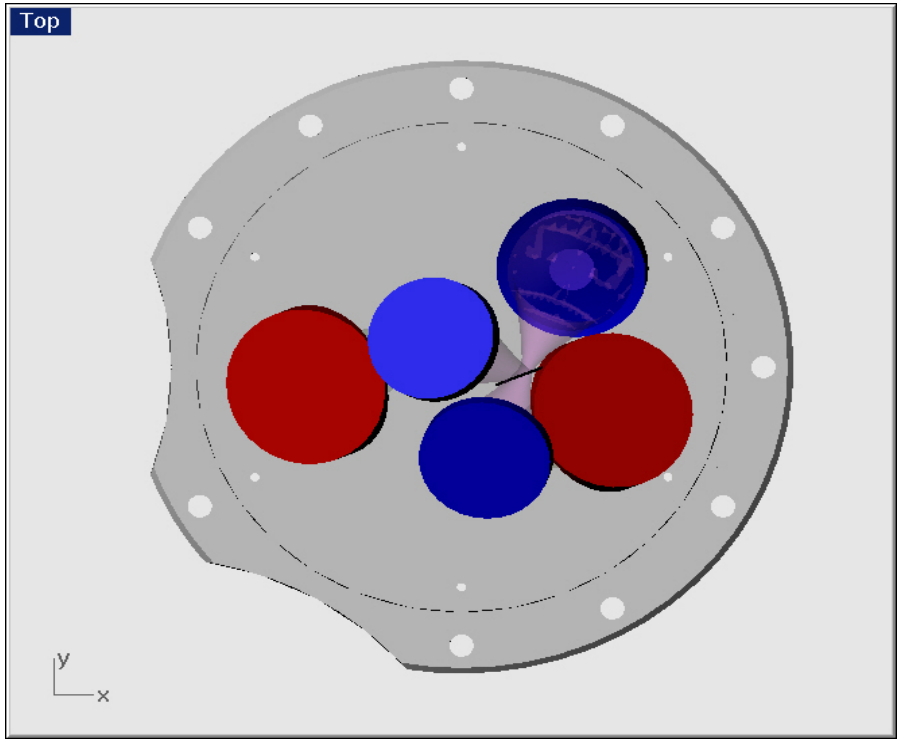
All together



Cartridge fit







Now to hardware

Traditional:

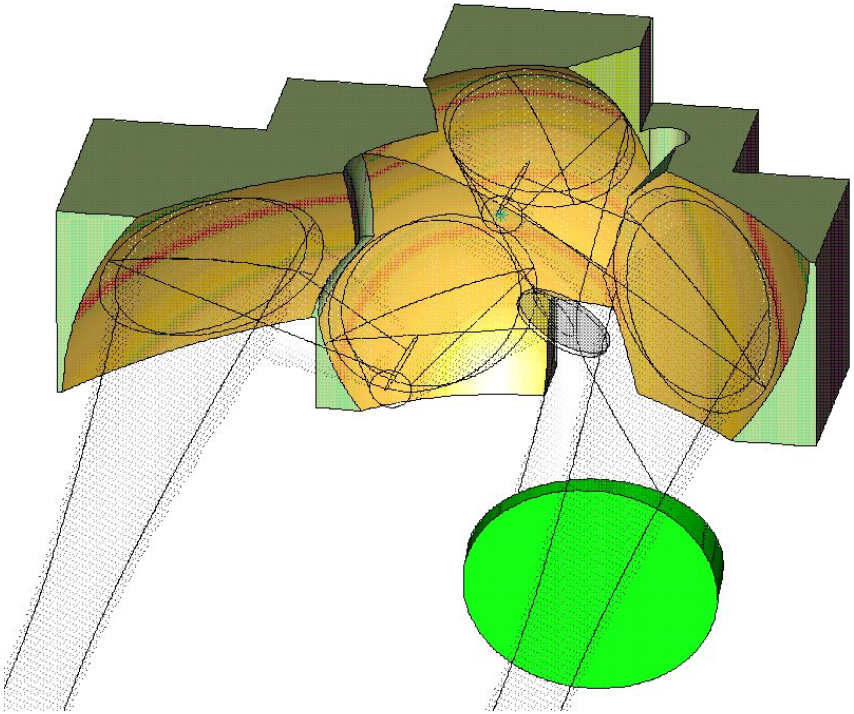
- 5 separate mirrors suspended and tuned in a frame
- Advantage: Tuning possibilities
- Large parts list

Alternative:

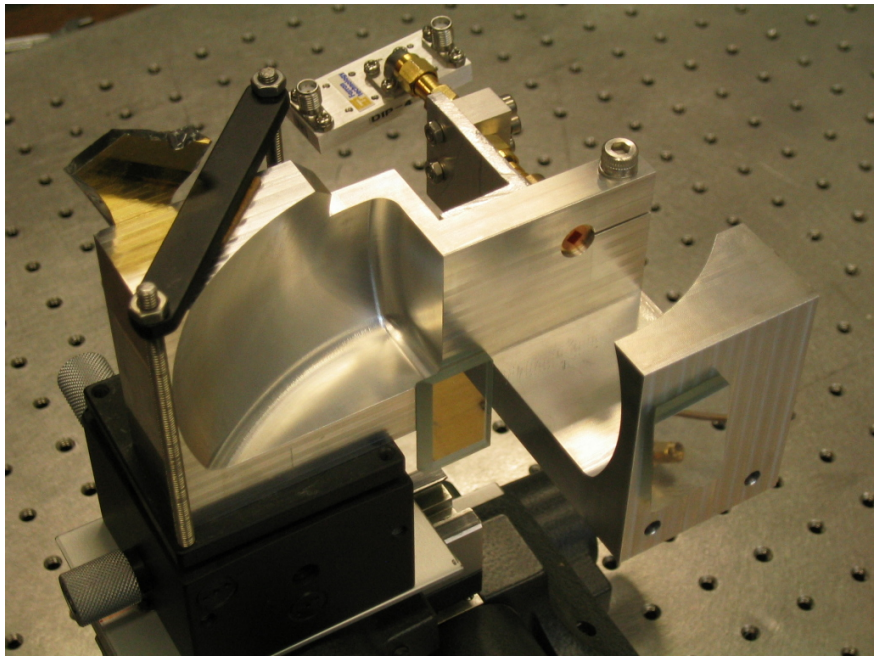
- CNC machining out of one block
- Advantage: No tuning possibilities
- Small parts list
- But will it work?

Integrated mirrors

Rely on CNC machine accuracy

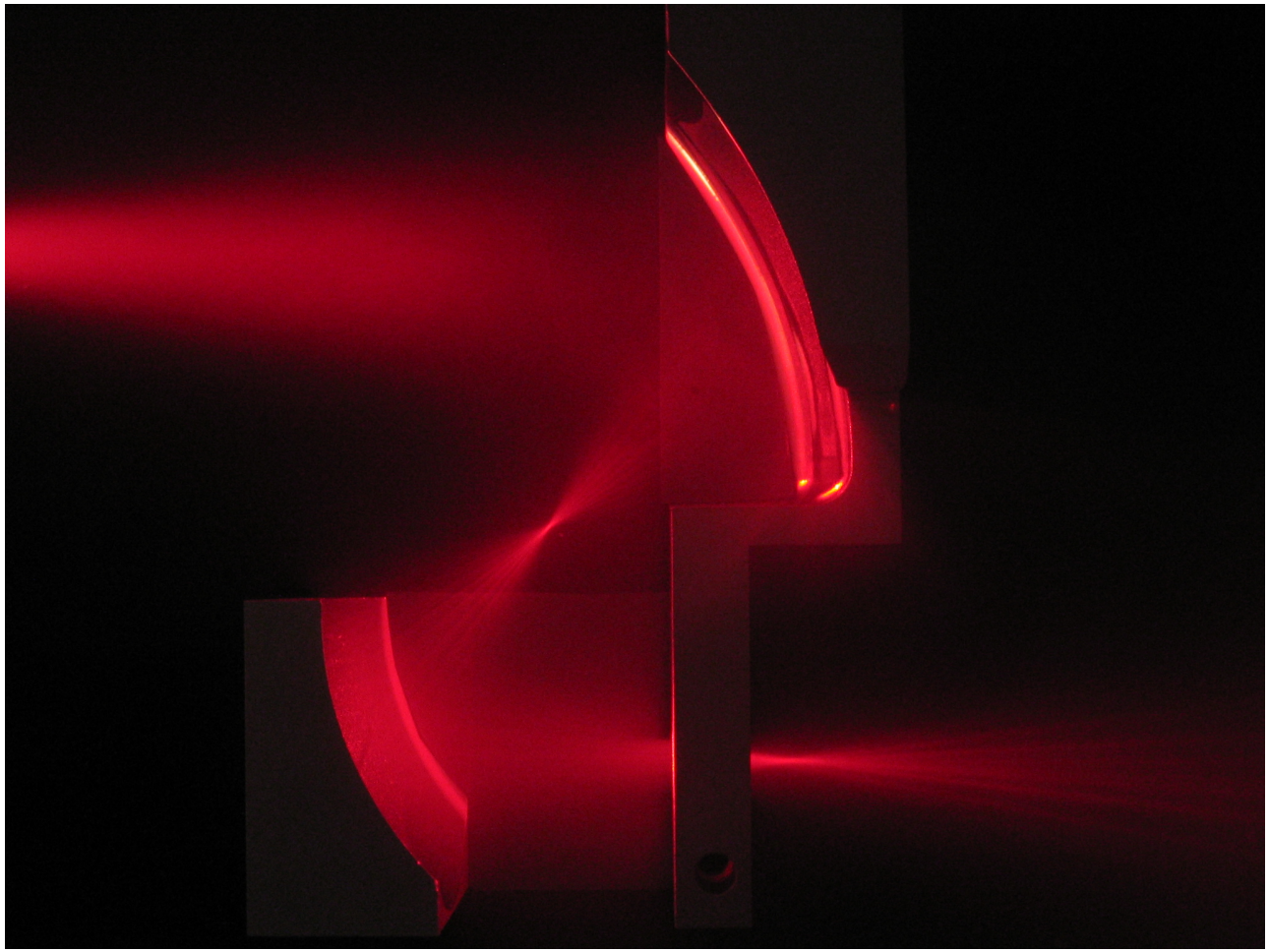


Integrated 4+1 Mirror Concept

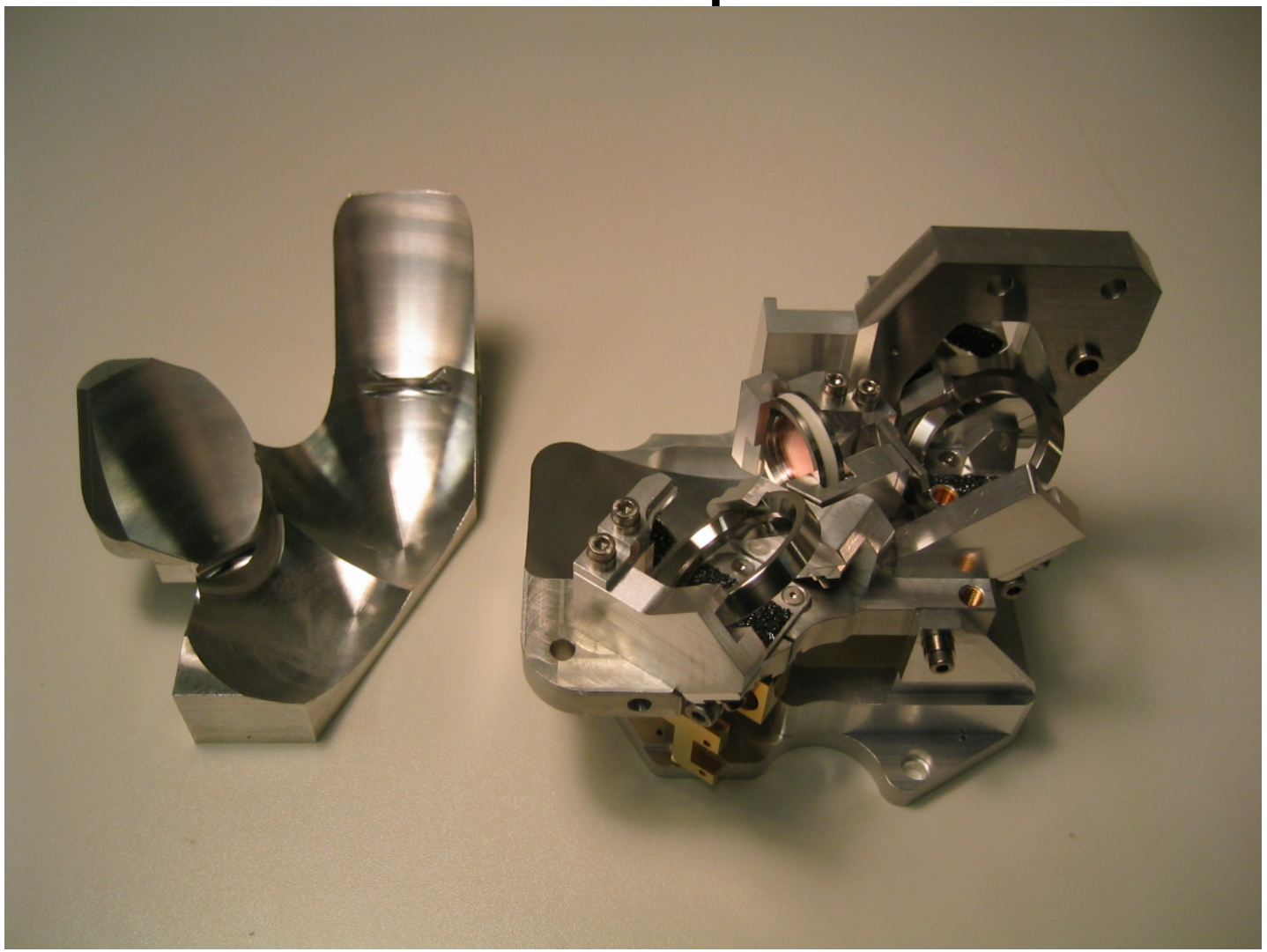


2 mirror block test block

2 Mirror block OK

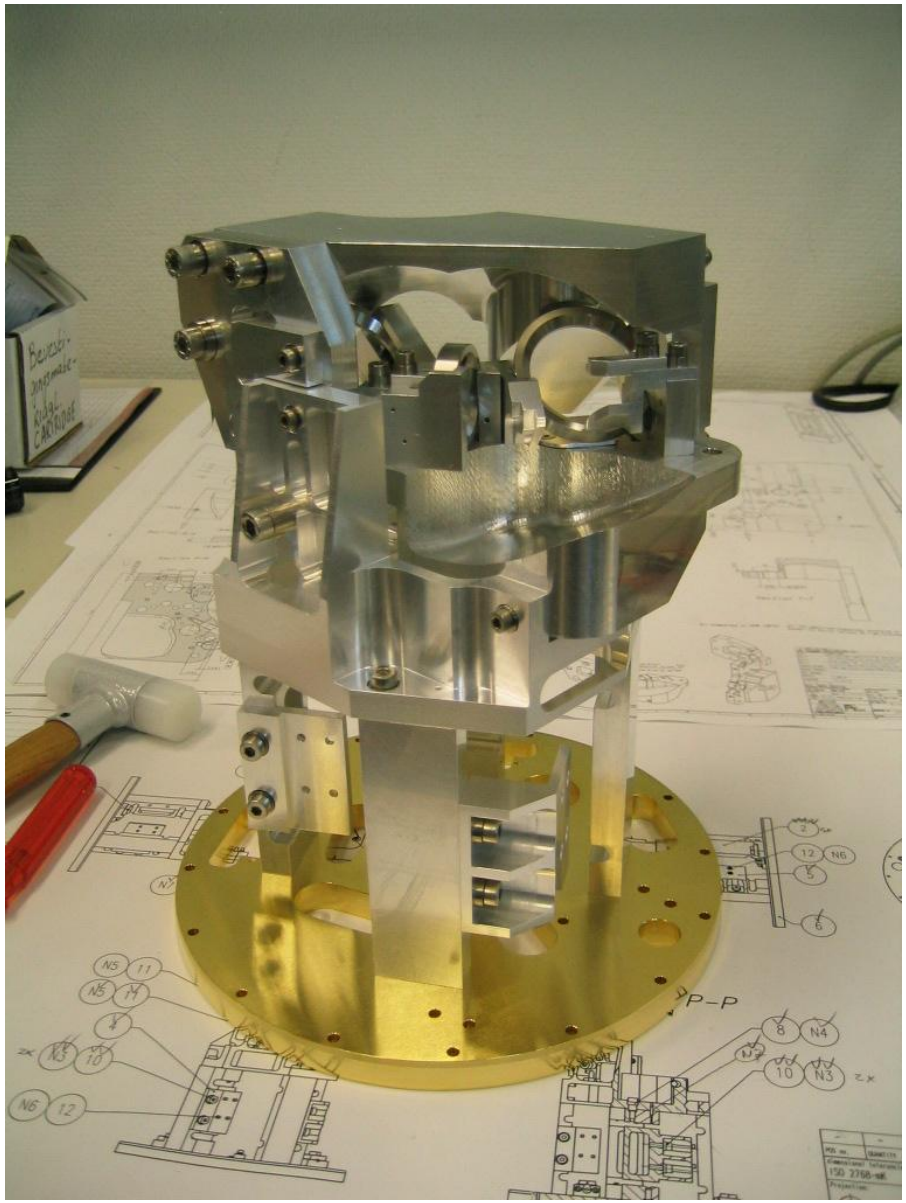


Real Optics



Disassembly + Assembly does not degrade optical quality

Optics on 4K level



Design example 2: Mixer

Easy to maintain again means: few components

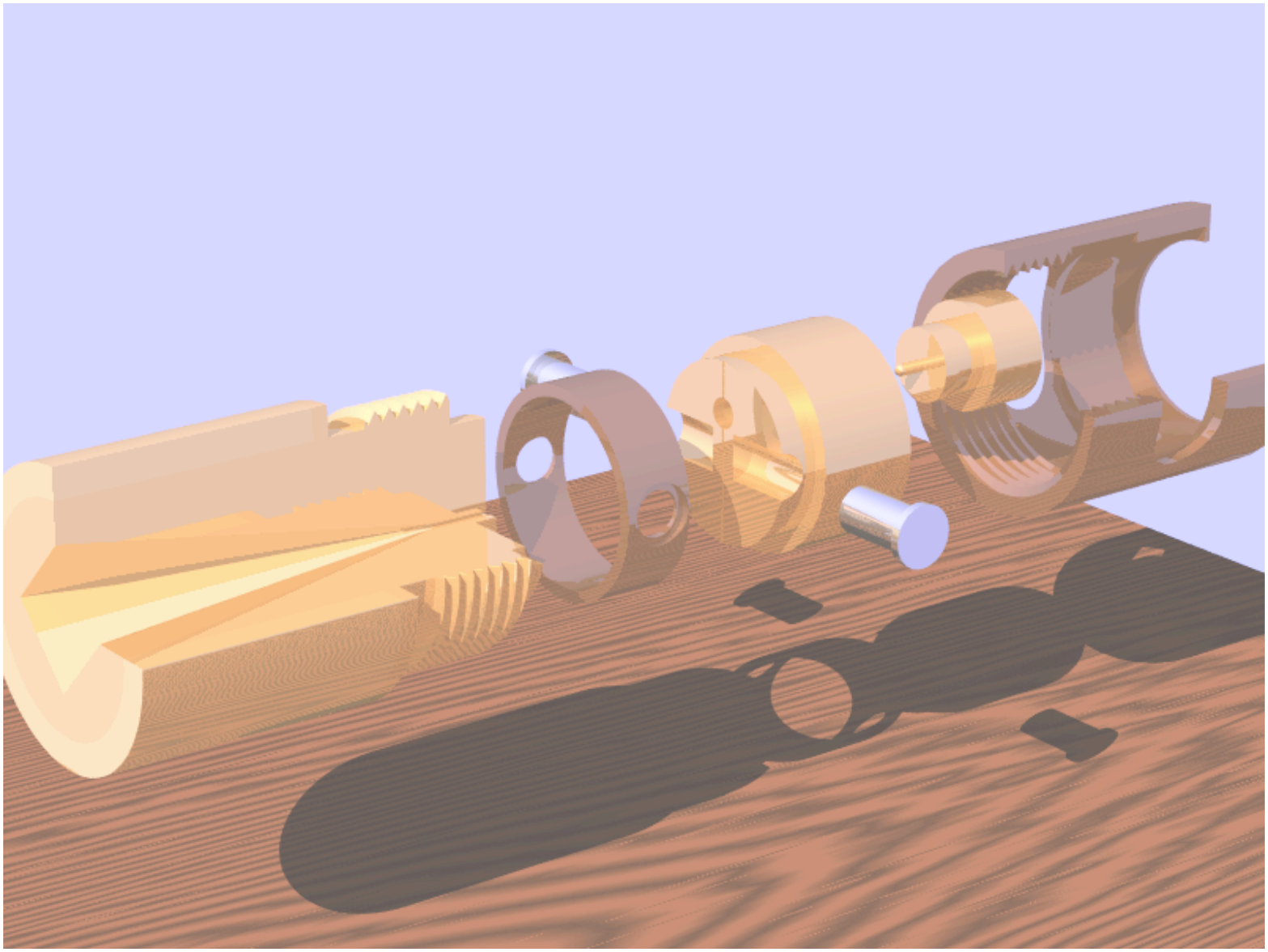
Swapping must be easy.

Best mixer in at the latest moment

Band 9 Mixer Design

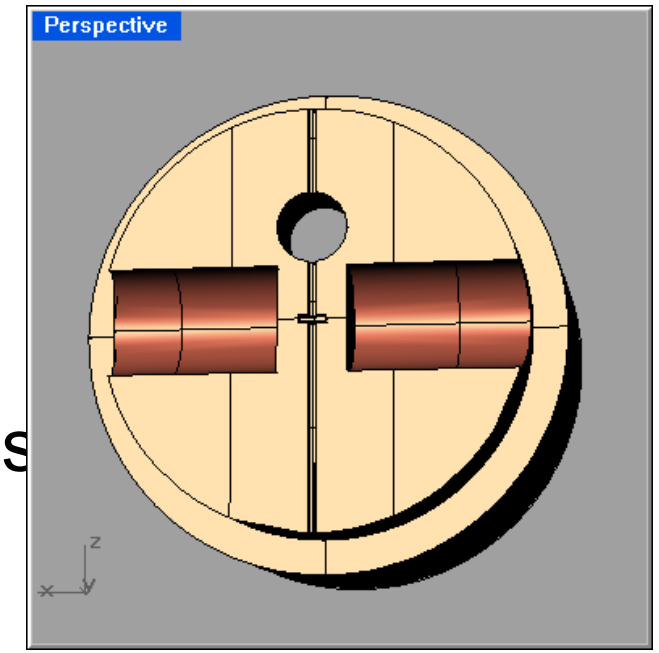
- Only 7 parts
- Mixer swap: 10 min.

Kalashnikov design



Mixer Block Techniques

- Fine mechanics
  - Machining of small structures (0.07x0.9 mm)
  - High precision ± 10 μm
  - Automatic alignment of tools
  - Different machining techniques
    - Diamond tool
    - Stamping cavity



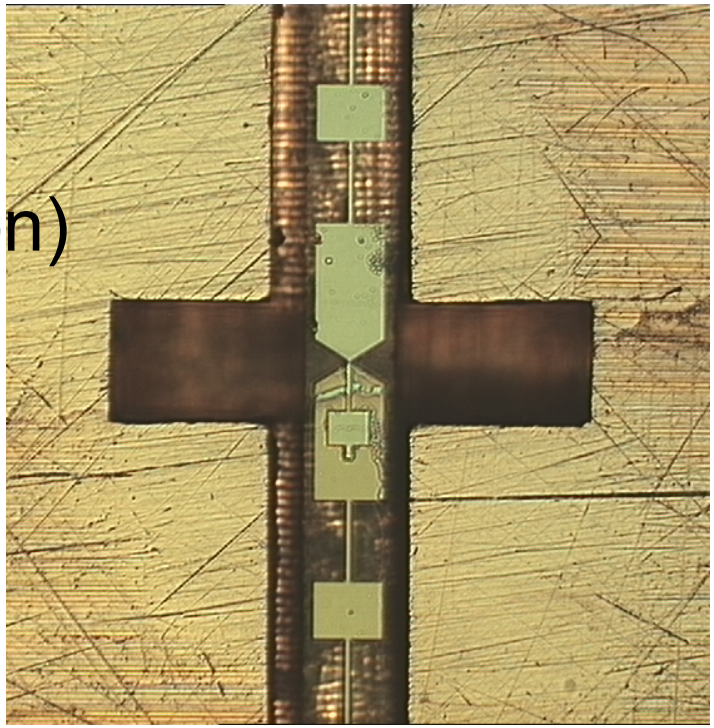
- Precise mounting techniques/ aligning by tolerances

Mixer / Mixer Block Technologies

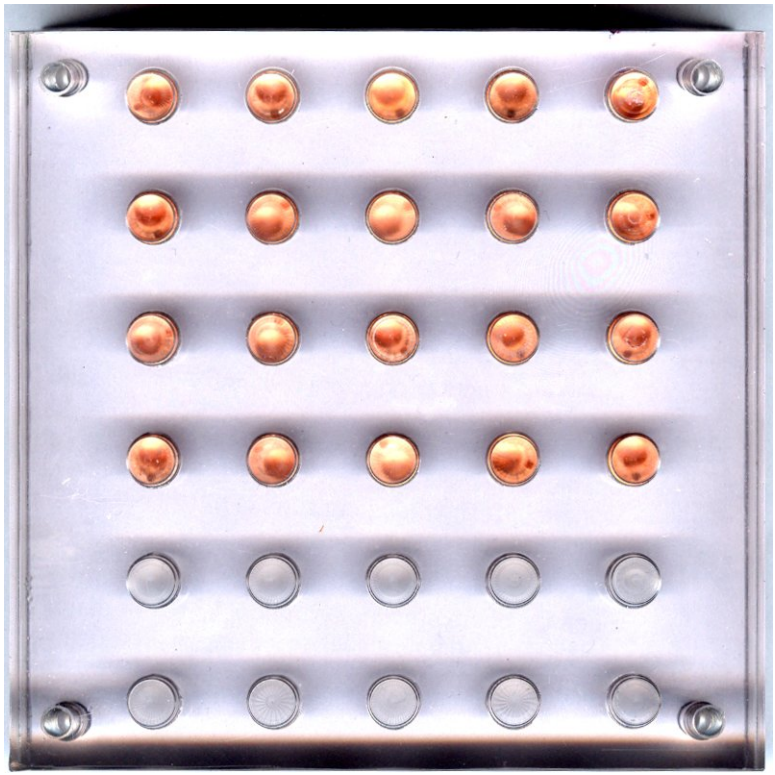
- Cryogenics/vacuum techniques
  - Heat conducting materials/straps
  - IR shielding/filtering
  - Special set of materials (outgas rate)
  - Material properties at cryo-temperatures
- Magnetic coil
  - Superconducting wire winding
  - Magnetic field conductors

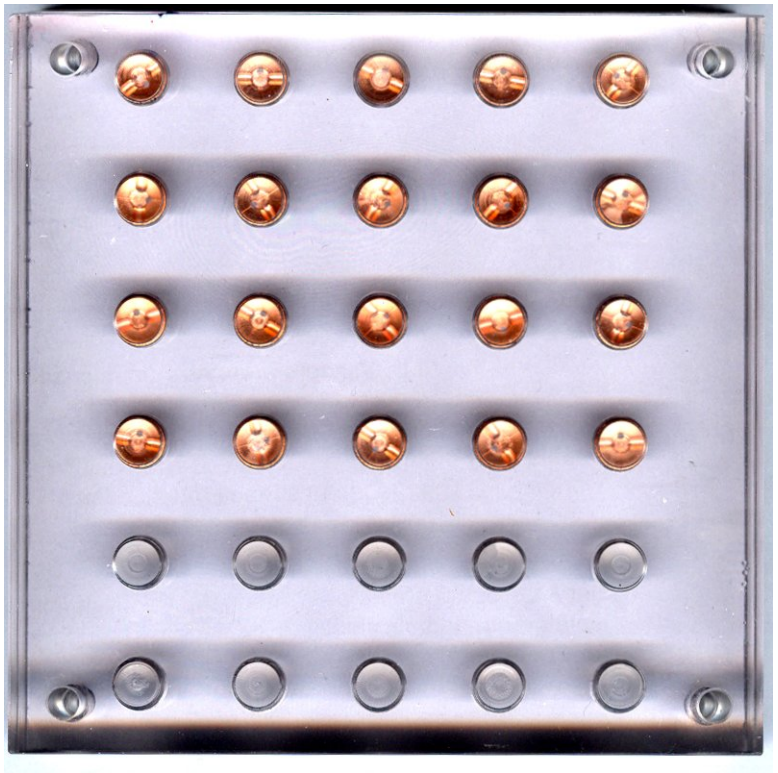
SIS Junction Technology

- Junction production
  - –High vacuum thin film deposition
  - –Trilayer growth (controlled oxidation)
  - –E-beam / optical lithography
- Mechanics & mounting
  - –Polishing and dicing
  - –Accurate mounting
  - –Gluing/making contact



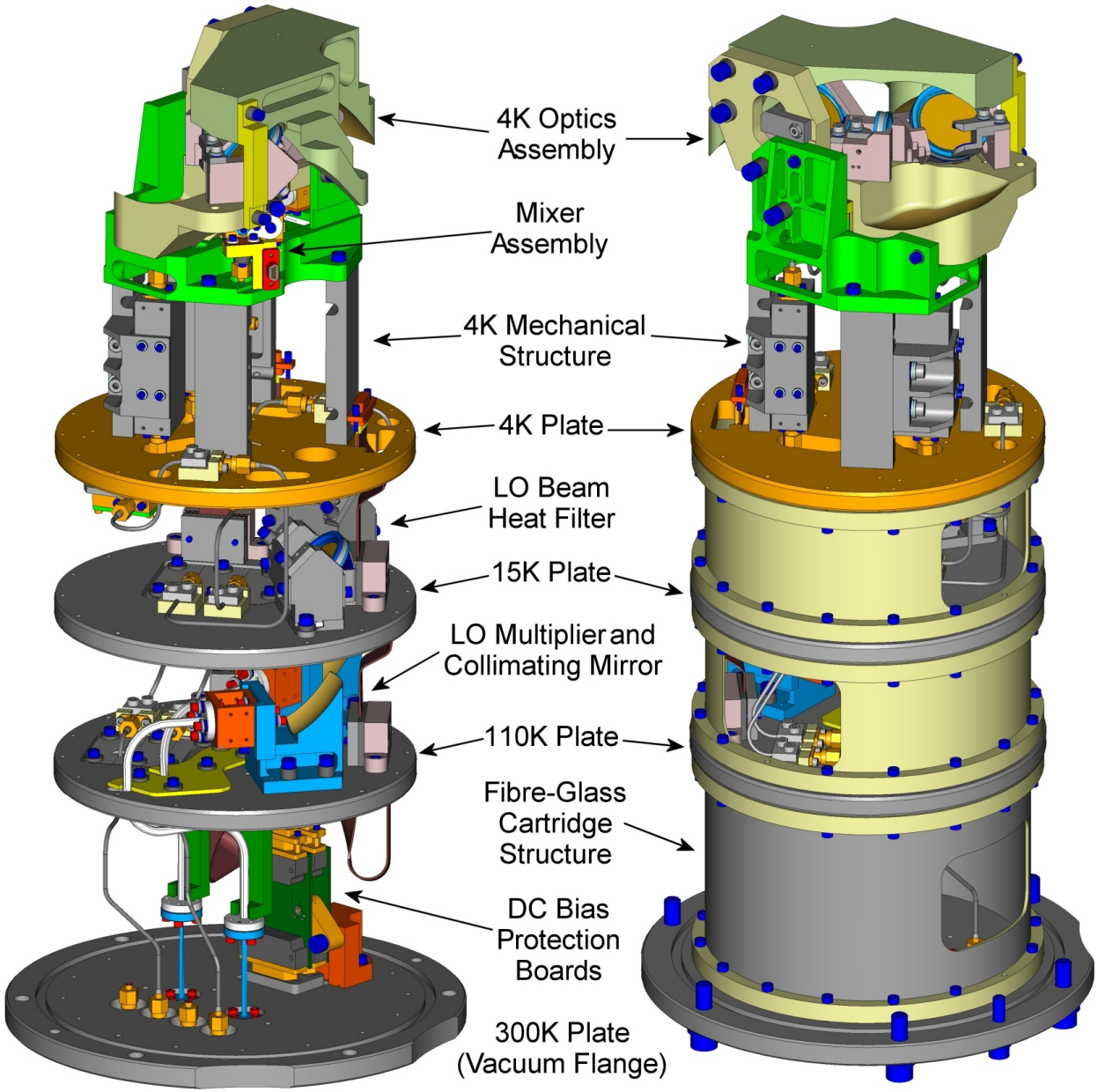
Witec Backpiece series production





20 Backpieces (front and back)

Band 9 end result



And now: 73 times

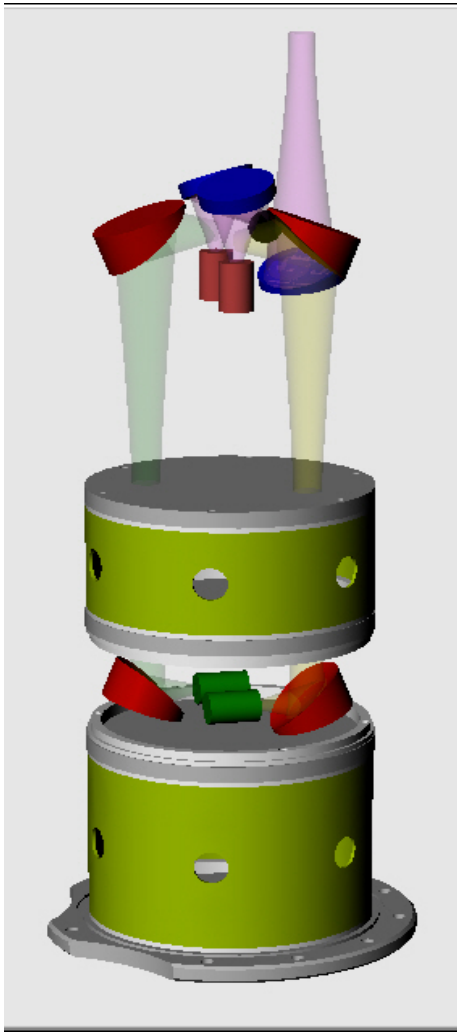
And now: 73 times

And now: 73 times

All quite
the same!

Technologies Involved 1

- Precise machining of mirrors 7 mu RMS surface accuracy
- Alignment by machining
- Cryogenics temperatures
- Complex opto-mechanical design
- Ultra high vacuum
- Wire grid production



Technologies Involved 2

- Cryogenics system
- Quasi-optical systems alignment verification
- System performance verification and feedback
- Beam pattern measurements
- Mirror surface verification
- Self aligning techniques: 4 mirrors from 1 block

Outsourcing

Band 9:

- 249 suppliers
- About 40 serious ones

Band 9 result

- Production phase: 65 receivers
- Duration: 4 years
- Finished: 3 months early
- 1st receiver which was ready
- 10% within budget

Band 5

- GARD, Sweden: 6 prototypes
- NOVA: Some (?) redesign + Production
- Redesign: use Band 9 experience
- GARD will produce mixers

Integration experience: Optics

Band 5 holds 2 mirrors:

GARD design: 6 parts with 27 dowel pins

NOVA design: One part out of one block

Band 9 → Band 5

A nine to five job?

With all our Band 9 experience?

Not really

Thank you for your attention