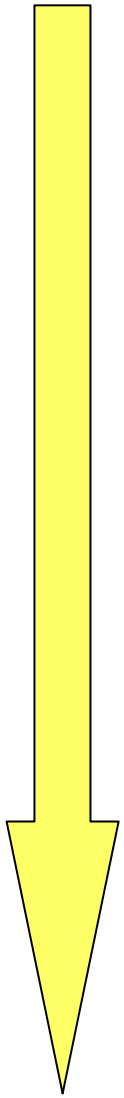
Ramam Laser Spectrometer (RLS) para Exomars: estado actual

Raman en ExoMars y su evolución



2002: primer estudio ExoMars (CDF)- Lanzamiento 2009

2003: Primera llamada a propuestas carga útil

Raman (externo/interno) + LIBS (externo/interno)

2007: Confirmación Carga útil – Fase B – Lanzamiento 2011

2008: Raman (externo/interno) + LIBS (externo)

Raman (externo/interno)

PDR de Sistema – Lanzamiento 2013

2009: PDR de Instrumentos

PCR#2 Redefinición Misión (sin brazo externo) – Lanzamiento 2018

Comienzo Fase B Extendida

Raman (interno) + muestra en polvo + nuevo concepto espectrómetro

2011: Delta-PDR de Sistema

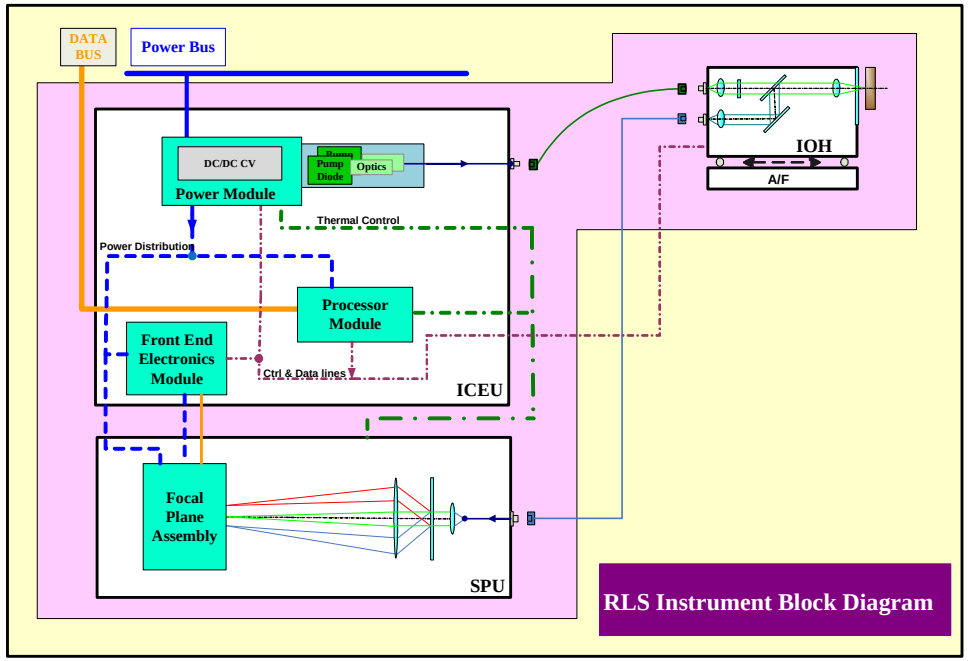
Preparación fase C/D

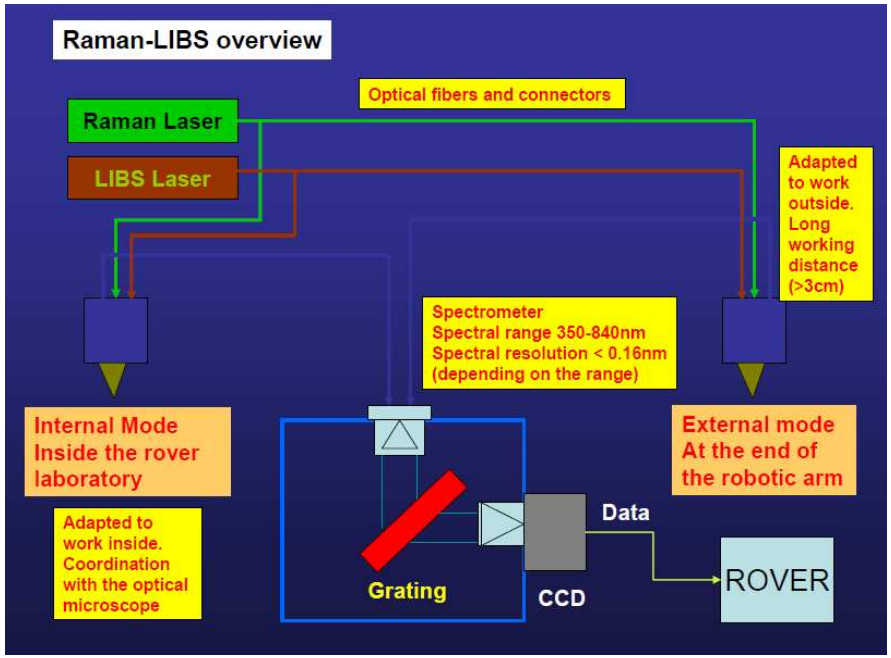
Redefinición Rover único- ¿Nueva fase B?– ¿Lanzamiento 2018?

RLS: Diseño

The Raman Laser Spectrometer (RLS) is one of the Pasteur Payload instruments onboard ExoMars 2018. It weighs ~ 2.3 kg.

The RLS Instrument will perform Raman spectroscopy on crushed powdered samples inside the Rover's ALD (Analytical Laboratory Drawer).

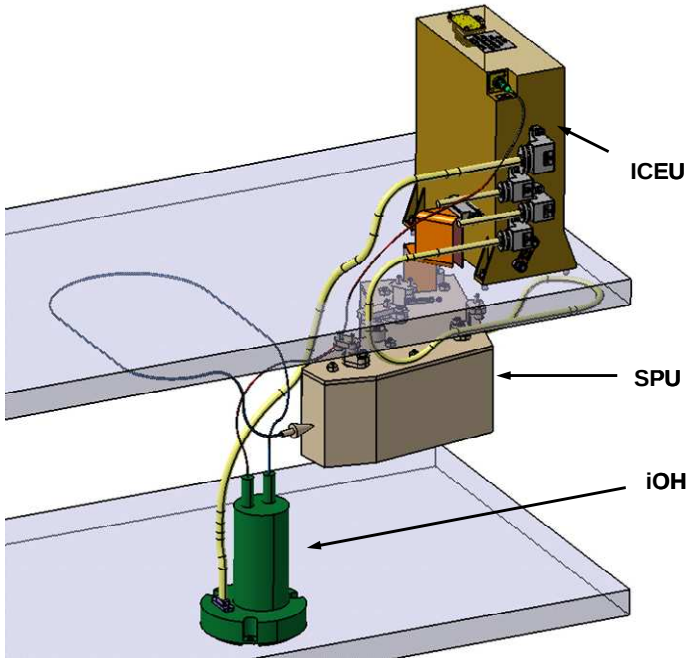


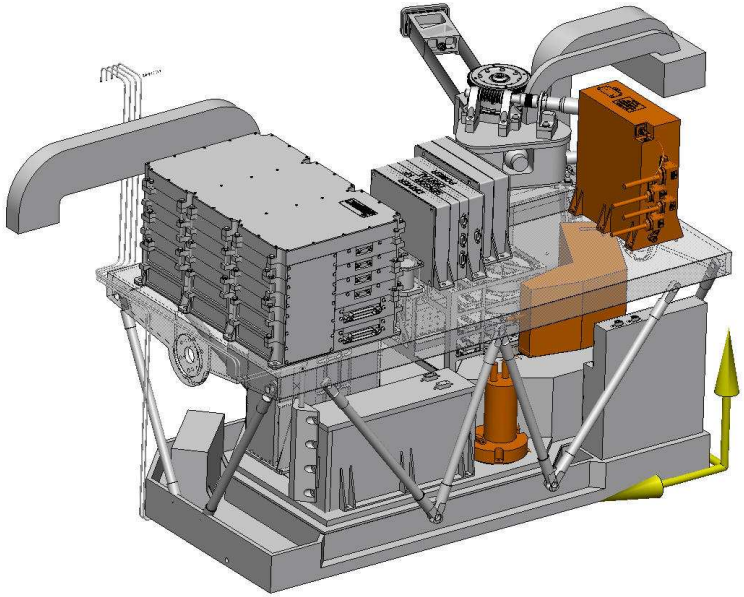


RLS: Diseño

The RLS Instrument is composed of the following units:

- **SPU** — **Spectrometer Unit**
- **iOH** — **Internal Optical Head**
- **ICEU** — **Instrument Control and Excitation Unit, including as well the Laser**
- **Others: Electrical & Harness, optical harness, software and the calibration target.**

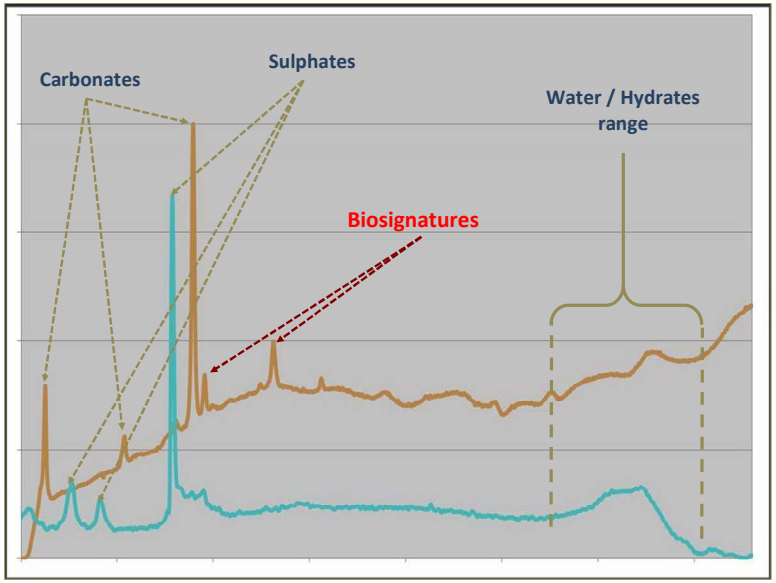




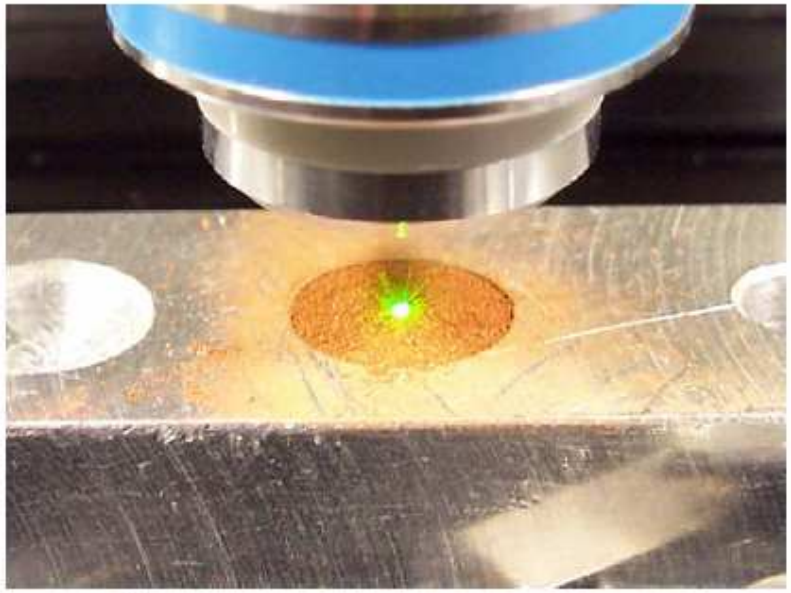
RLS: Diseño

Principales características del instrumento

- **Laser excitation wavelength: 532 nm**
- **Irradiance on sample: 0.6 – 1.2 kW/cm^2**
- **Spectral range: 150-3800cm-1**
- **Spectral resolution: 6 cm-1 lower spectral wavenumbers; 8 cm-1 long spectral wavenumbers**
- **Spectral accuracy: < 1 cm-1**
- **Spot size: 50 microns**



Science capabilities within Raman Shift range of 100-4000 cm-1



RLS: Equipo de Trabajo

The Team

España:
Investigador Principal (PI)
Instrument Project Manager (IPM)
Organización y gestión del consorcio europeo
Garantía de Producto y protección planetaria a nivel consorcio
Ingeniería de Sistemas del Instrumento
Montaje, Integración, Verificación, y Calibración a nivel Sistema
Ingeniería de Operaciones
Segmento Terreno: contribución científica al centro de operaciones
Desarrollo del espectrómetro (con contribución de otros países)
Desarrollo del Láser ubicado en la unidad electrónica (ICEU)
Desarrollo de cableado entre unidades
Desarrollo de SW embarcado
Desarrollo de equipo soporte a nivel sistema

Alemania:
Desarrollo del cabezal incluyendo mecanismo de enfoque y electrónica asociada.
Desarrollo de las conexiones ópticas: fibras ópticas y conectores

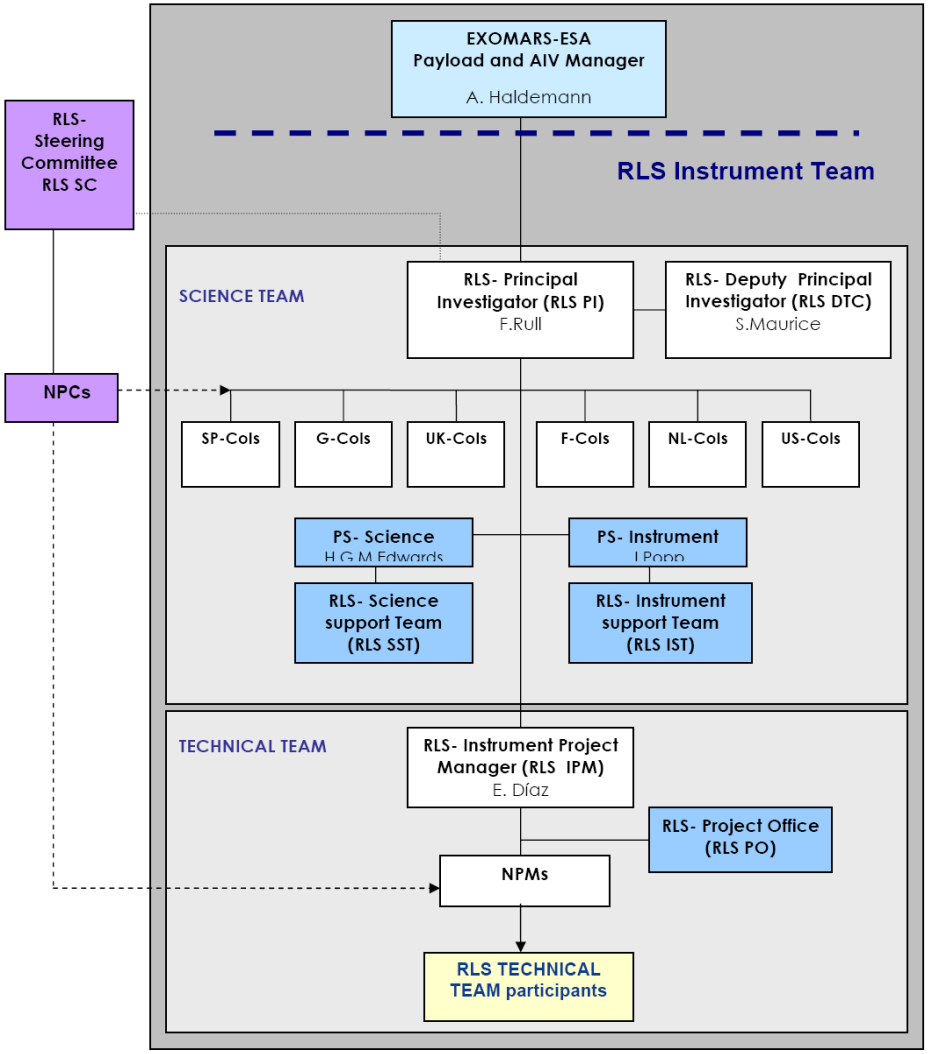
Reino Unido:
Desarrollo del detector CCD del espectrómetro y electrónica de proximidad ubicada en la unidad electrónica (ICEU)

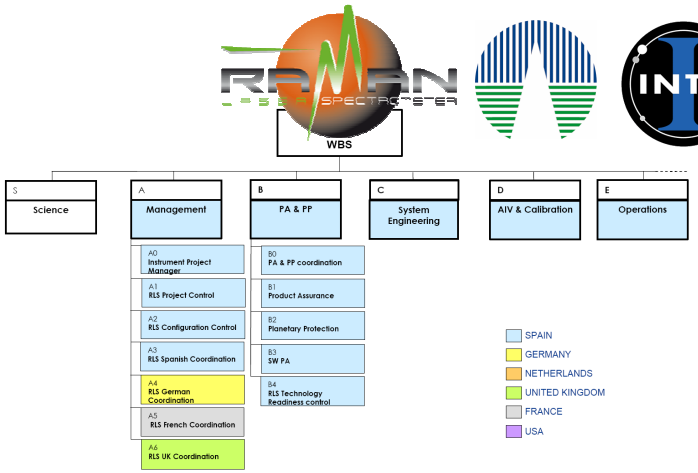
Francia:
Adjunto al Investigador Principal (Co-IP)
Desarrollo de la Unidad electrónica (con contribuciones de otros países)
Participación en la calibración del Instrumento

Holanda y USA:
Contribución científica

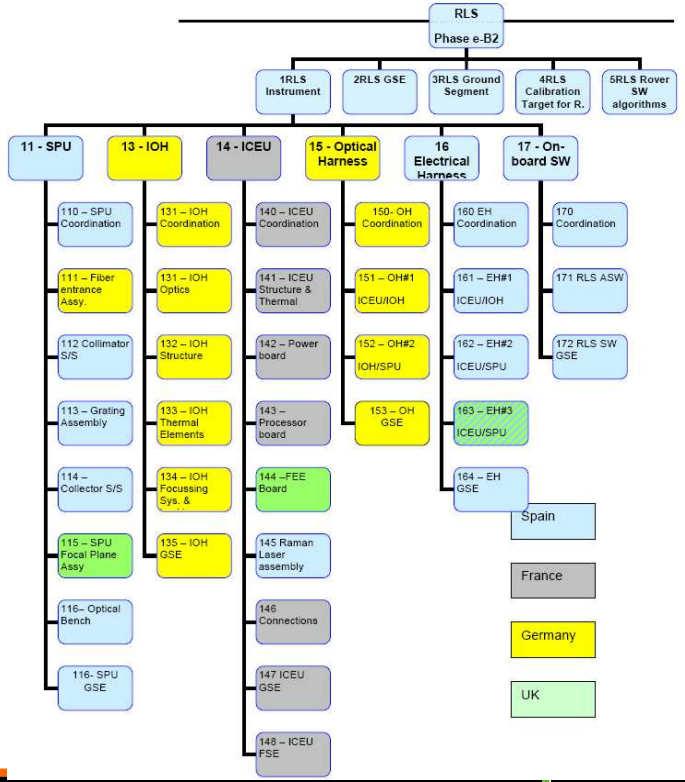
RLS: Equipo de Trabajo

OBS: Organisation Breakdown Structure

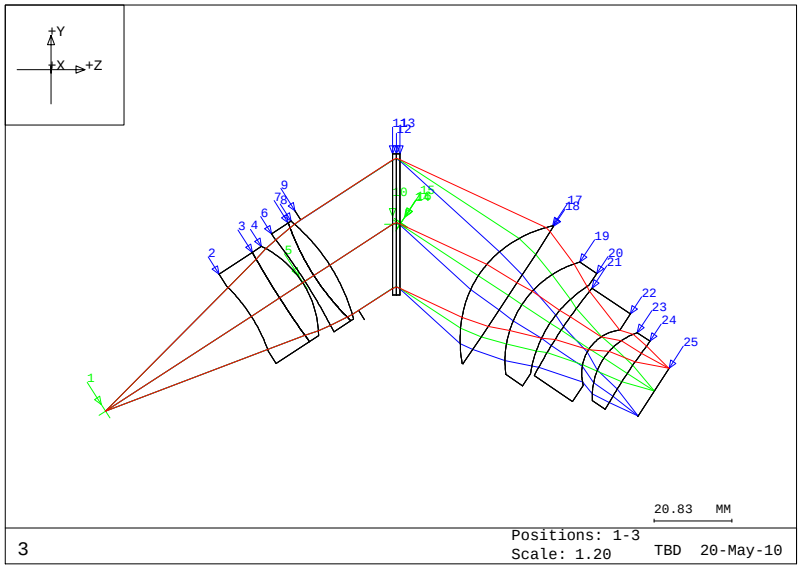




WBS: Work Breakdown Structure

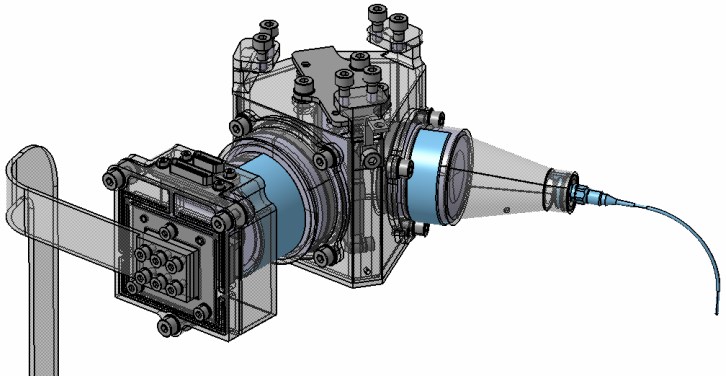


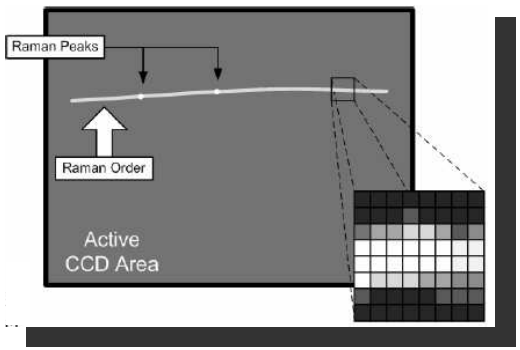
RLS: Diseño

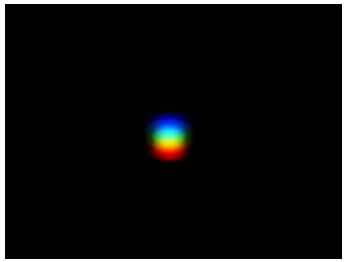


SPU: Spectrometer Unit

- **Spectral dispersion of Raman light by means of transmission optics**
  - **Simple holographic grating: 32.8ºAOI ;1800l/mm ; λχ = 603 nm; Efficiency ~75%**
  - **Input AN 0.22**
  - **Magnification 0.7**
  - **EFL 69.5 mm (Collimator)**
  - **EFL 48.8 mm (Collector)**
- **Registration of light on the e2V CCD (2048x512 pixels)**
- **Transfer of analogue signal to ICEU**
- **Active cooling for CCD temperature control by means of a TEC device**







SPU Design Evolution

SPU Reflexion Concept

TNO- Netherlands

2009

PCR2 recommendations were to increase:
- RLS spectral resolution => main impact in grating.
- Powdered samples=> lower Raman response => RLS throughput=> increase luminosity => main impact in size and focal of the optics.

+RLS mass exceeded + SPU design maturity + SPU thermal accomodation in the ALD

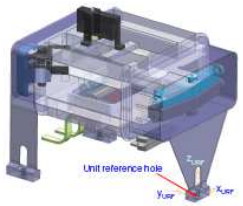
Oct 2009

SC Meeting: **SPU Transmision concept selected** => more compatible with ALD thermal I/F, less sensitive to thermal gradient, better resolution and , more flexible to future changes. Important to start Grating Validation Plan =>**Spain**

June/Oct. 2009

SPU trade-off
(Relfexion vs. Transmision concept)

Lots of SPU design alternatives that have been studied to improve resolution, to reduce mass, to improve thermal design



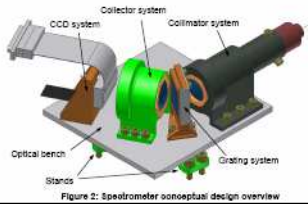


Figure 2: Spectrometer conceptual design overview

SPU Detailed Prelim. Design => "normal" work.

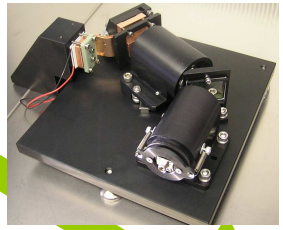
Jan 10

SPU baseline fixed => go ahead SPU BB manufacturing (maintaining+ 2 grating backups envelope)

April 10 IF Teleccon

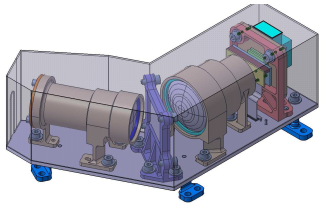
SPU baseline fixed + 2 grating backups not no exeed envelope ALD interferences.

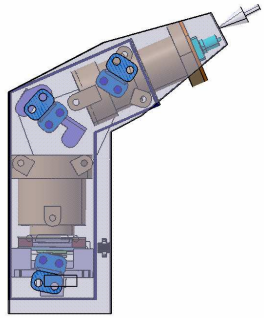
Alternatives studied:
- Folding Mirror
-Change of NA optical fiber.
- 0.7 Magnification



SPU Design Evolution

May 24th 2010 IF/ Meeting => go ahead (up side-down).

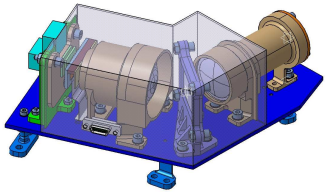


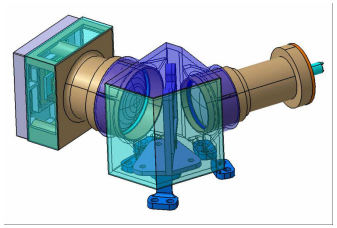


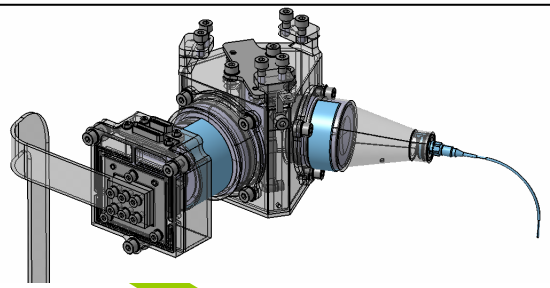
TASI I/F meeting **November 3rd** 2010 => TASI detected some mechanical interferences with MOMA (due mainly to LMC in ALD)

Q3 & Q4 2011: RLS Co-DR & SPU Co-DR (+ Grating procurement to be started => Grating CDR!!!) & lenses validation

Febr. 2011 => Internal SPU trade off (thermoelastic performance in the complete operative range (+ envelope reduction))



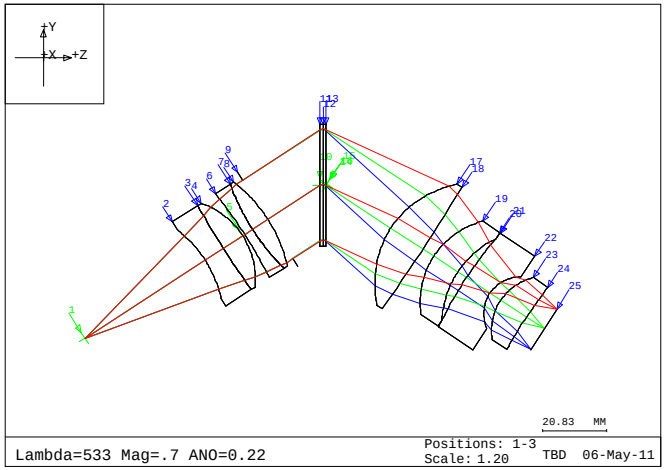




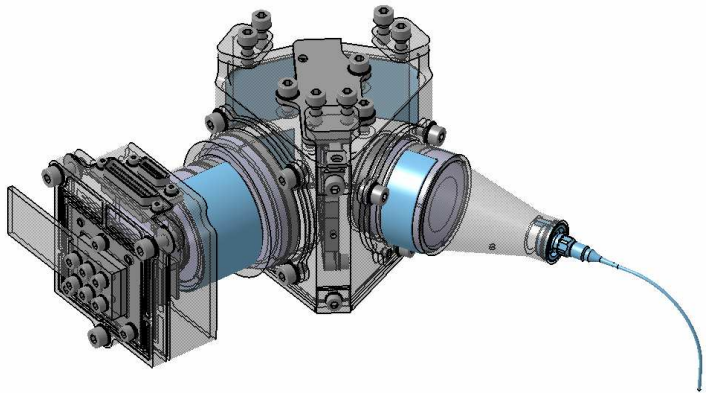
Q2 2012 => Grating & Optical lenses **Qualification** to be started.

Current SPU Performances & Design

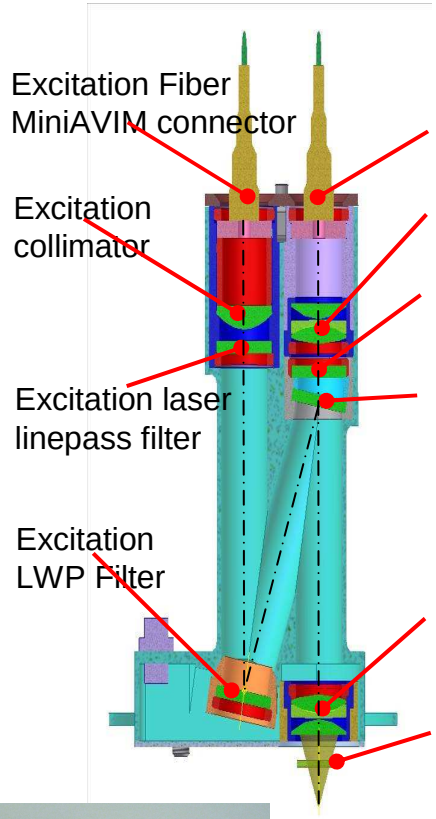
	Current Status
Focal Length COLLIMATOR	69.53mm
Focal Length COLLECTOR	48.77mm
M	0.7
AN	0.22
Input Fibre	50µm
Image	35µm
Pixel size	15µm
Spectral Range	533-676nm
Extension (pixels)	~1200
Resolution	0.12-0.15nm/pixel
Dispersion	8-10nm/mm

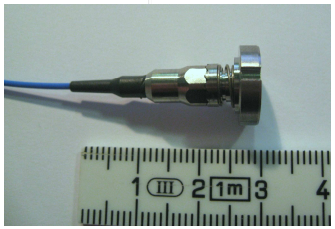


TRP	IRD 7.0		E-ICD	
	Min	Max	Min	Max
CCD	-40	-10	-40	6 (TEC)
SPU	-40	-10	-40	0



RLS: Diseño





MiniAVIM receptacle

Off-centered actuator

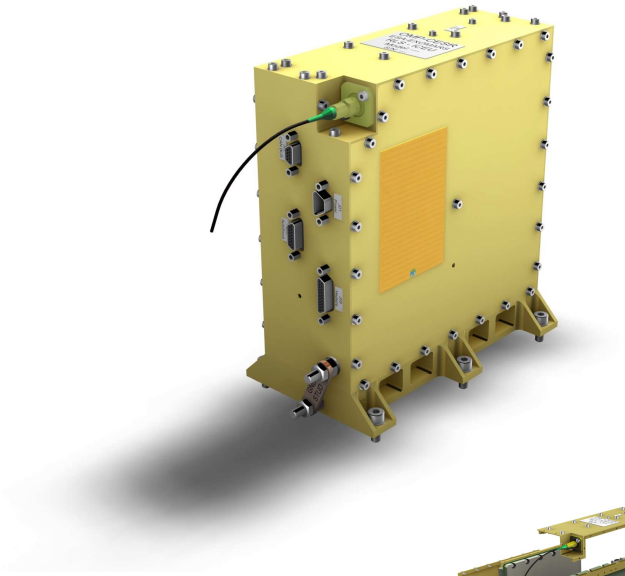
IOH: Internal Optical Head

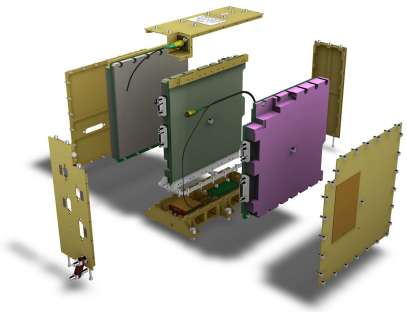
- **Active focussing of Laser excitation signal onto the sample (powder) of ±1mm range and 2 µm resolution**
- **Reception of Raman signal emitted by the sample and focus it on the fiber of the optical Harness (OH)**
  - **Simple aspheric excitation collimator**
  - **Corrected front lens and reception collimator for 537-670nm**
  - **Mini-AVIM receptacle for fiber optic connectors**
  - **10 deg Raman edge filter to ensure near Raman cut on (< 200cm-1)**

OH: Optical Harness

- **Optical fibers: Transmission of laser light from ICEU to iOH and Raman light from iOH to SPU**

RLS: Diseño



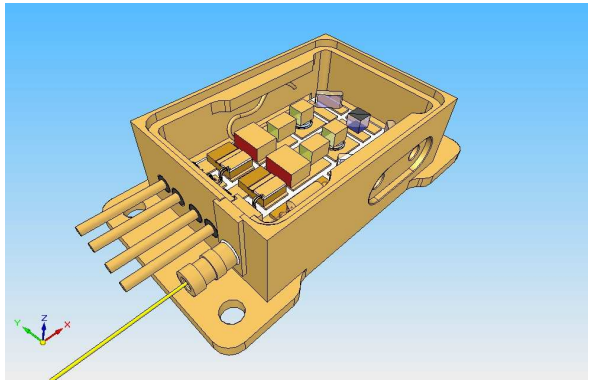


ICEU: Instrument Control and Excitation Unit

- CCD clocking, control and readout by means of Front End Electronics (FEE)
- Laser source and Laser control electronics
- Data processing capabilities (8 bit µcontroller, 4MByte RAM, 20 MHz, CANBus communications)
- Internal DC/DC CVs (35 W installed) supplied from +28 V
- Actuator (IOH Autofocus) control, instrument thermal control and HK provisions

Laser main characteristics

- Laser output power between 32,5 and 39,5 mW
- Excitation signal of 531.45 +/- 0.5 nm; FWHM < 0.03nm
- Redundant excitation



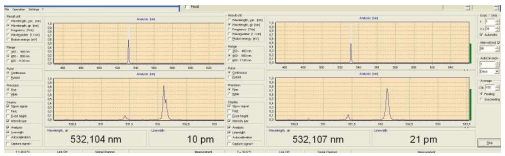
Compact redundant laser source

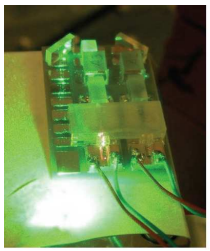
Laser Design Evolution

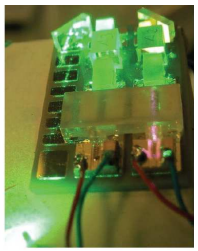
Laser YAG Concept

532nm

35/50mW







2007

- 2 Laser for Raman spectroscopy: one for the External head and one for the internal head
- 100mW of output power

Laser Vanadate Concept

531.45nm

100mW

2009

PCR2:

- External head removed: only one laser chain => redundant concept needed
- Narrower bandwith required
- Reduction of Laser output power

RLS: Estado de desarrollo tecnológico

TRL 5 Assessment Plan

It was required by ESA to all ExoMars Instruments that:

►All instruments must achieve a TRL 5 by the ExoMars Instrument for Δ PDR

► The breadboard used to achieve TRL 5 must demonstrate the "form and function" of the eventual flight unit (out of the set of "form, fit, and function“).

►“form and function” for PDR still implies flexibility in the breadboards, within the boundaries conditions of providing:

►Demonstration that critical functionalities and/or interfaces work

►Strong arguments with evidence that support the development of the instrument chosen flight design

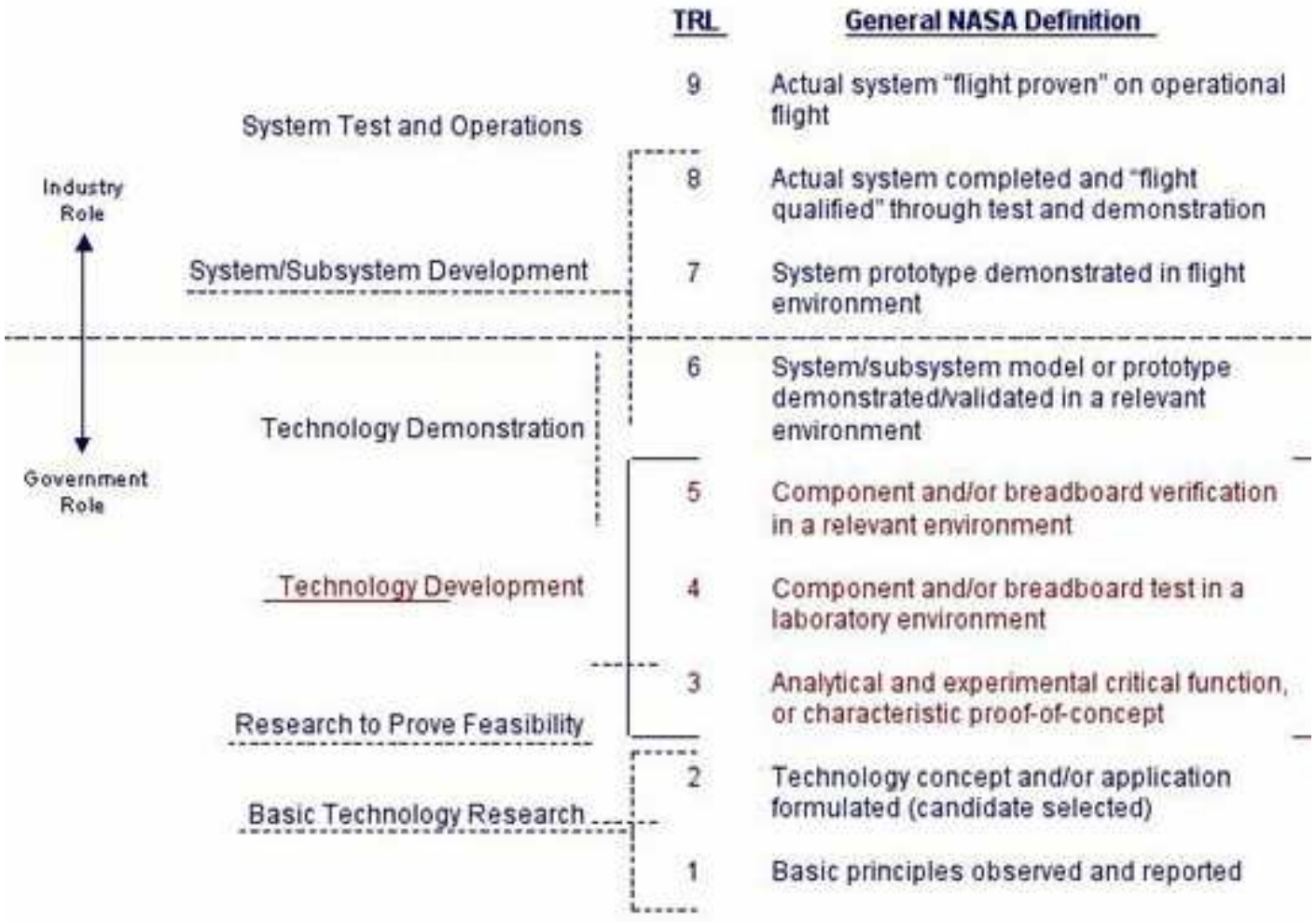
RLS: Estado de desarrollo tecnológico

RLS TRL 5 Assessment Plan

Such requirements are being tailored for RLS instrument, as part of a RLS TRL5 Assessment Plan; developing activities at three different levels, but carried out all together in parallel:

- ►Components, parts, material and processes VALIDATION & QUALIFICATION PLANS (including radiation tests campaigns)
- ►Unit S/S level: for achieving its own TRL5
- ►Instrument BB campaign

RLS: Estado de desarrollo tecnológico



Grating Validation Test Plan

VPH Transmission Gratings

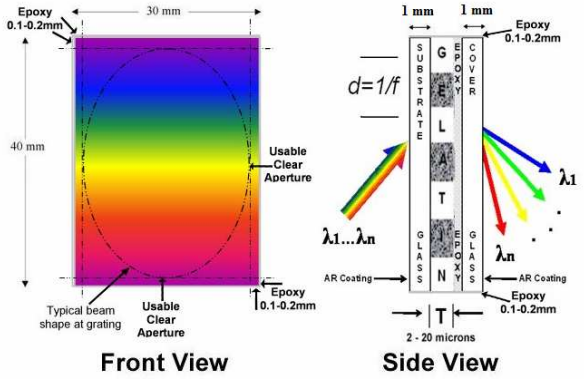
Dichromated Gelatin with diffraction pattern

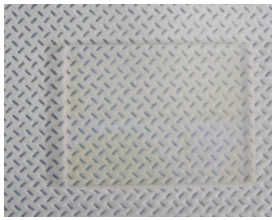
1800l/mm

AOD=AOD=32.84º

Fused Silica

Epoxy NOA61





15 gratings (VPHGs) and 9 samples of dichromated gelatine (DCGs) (DCGs are used as reference in case of any anomaly is observed in VPH)

Marianela Fernández	**Optical characterization. DUTs responsible**
Jose Antonio Rodríguez	**Non Operative TemperatureTest. AIV Engineer**
Gonzalo Ramos	**Optical characterization. Operative TemperatureTest**
Sergio Ibarmia	**Gamma and protons irradiation tests**
Concha González	**Optical characterization**
María Colombo	**SPU Unit Leader**
Paloma Gallego	**Validation Test Plan responsible**

Performed Test:

✓ **Non Operative** Th. Cycling (INTA): -70ºC to +70ºC

✓ **Gamma** (CIEMAT): Total dose: 20Krad (Si)
Irradiation steps (4): 5Krad (Si) – 10Krad(Si) – 15Krad(Si) – 20Krad(Si). After each irradiation step, optical characterization at INTA

✓ **Proton** (RADEF): 5 Irradiation steps: 5E9 - 1E10 - 2E10 - 4E10 - 8.8E10 @ 50MeV p+cm-2
Intermediate measurements at RADEF.

✓ **Gloss Leak** (INTA).

✓ **UV** (INTA/Spasolab).

✓ **Operative** Th. Cycling (8mbar): 20ºC & 0ºC to -40ºC.

Pending:

❑ Vibration & schock.

❑ DHMR.

TRL5 STEP1

SPU

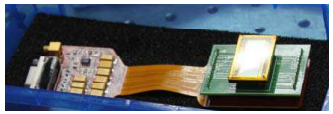
KOSI SPECTROMETER / COMMERCIAL

- Optics: f/1.8; focal length: 85 mm
- Notch Filter: at 532 nm
- Double Difraction grating

  Spectral Range: -29 to +4387 cm^{-1}

CCD BB1 / Leicester University

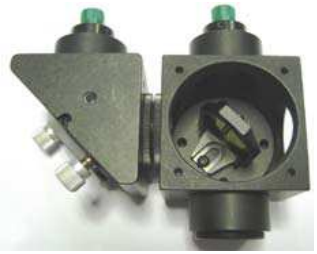
- 2048x512 pixels (13.5µm pixel)
- IMO; Back Illuminated
- -10ºC operated
- SW for spectrum obtaining

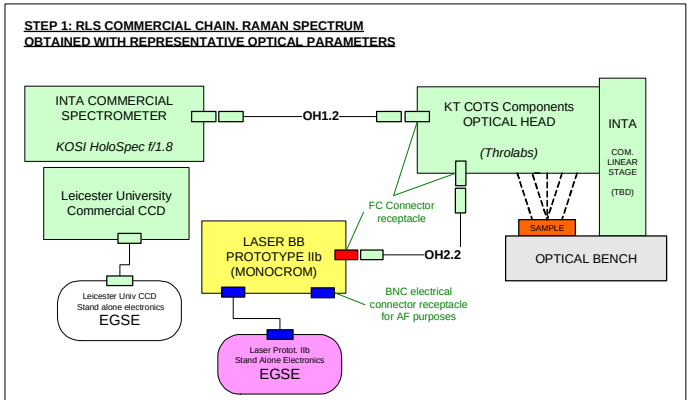


iOH

COTS iOH BB / KAYSER THREDE

- Optics functional representative
- NA 0.22
- FC fiber connectors
- Notch Filter: at 532 nm
- Focal Length: 8 mm
- No AF capability





RLA

Prototype IIb / MONOCROM

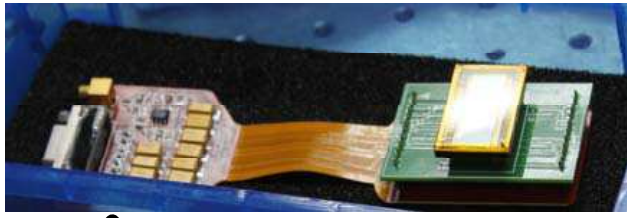
- Output power: ~ 50mW
- Ring mode performance
- AF diode

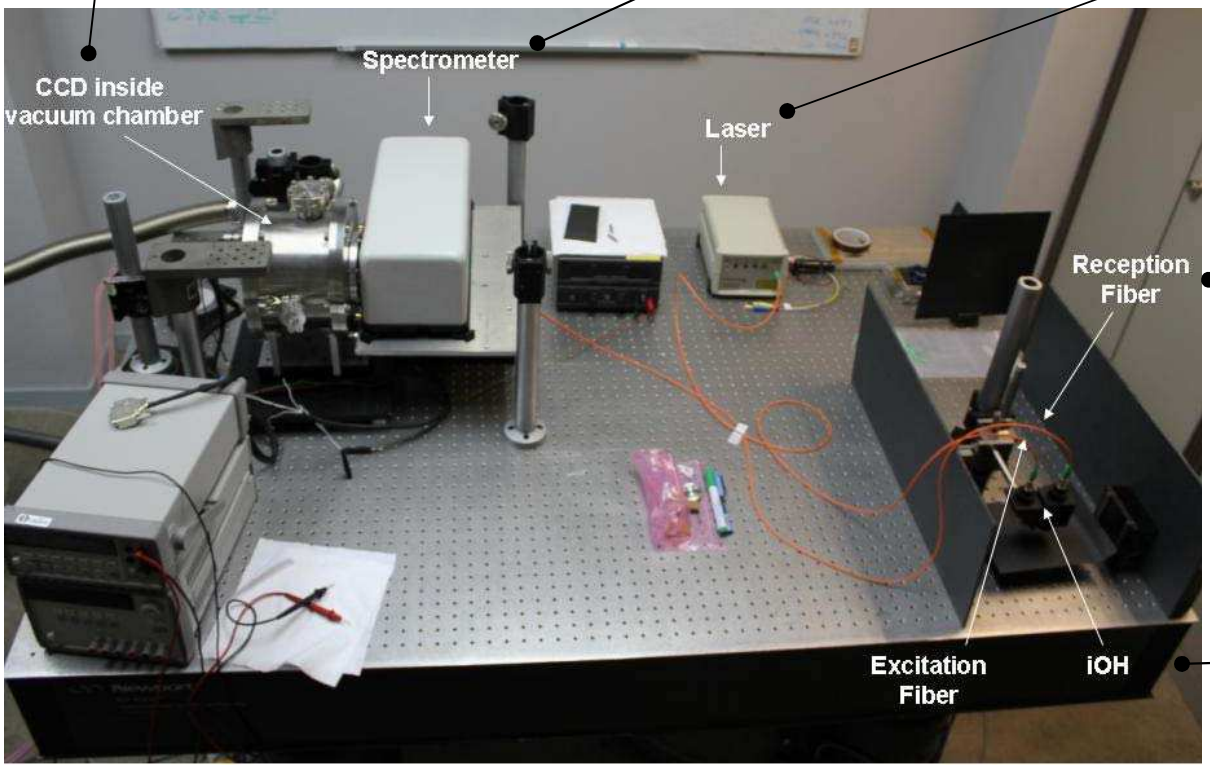
OH

COMMERCIAL / Thorlabs

- FC/APC-FC/APC patchcords; 50 µm core, NA 0.22

STEP 1




CCD inside
vacuum chamber
Spectrometer
Laser
Reception
Fiber
Excitation
Fiber
iOH

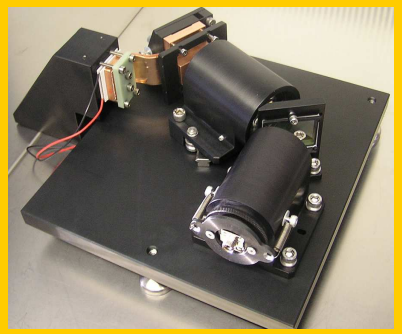
Custom Patch Cords in 24 Hours

TRL5 STEP2

SPU

SPU BB / INTA

- Optics: FM Like
- Grating: FM Like, simple transmission



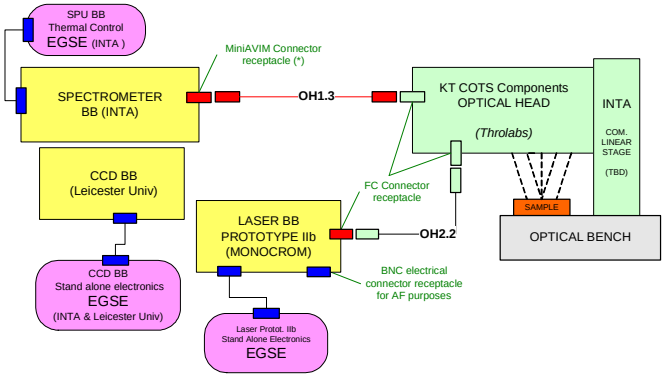
CCD BB2 / Leicester University

- 2048x512 pixels, 15 µm pixel (TBC)
- IMO; Back Illuminated (TBC)
- -10ºC operated
- SW for spectrum obtaining

iOH

COTS iOH BB / KAYSER THREDE

- Optics FM representative
- NA 0.22
- AVIM connectors
- Notch Filter: at 532 nm
- Focal Length: 8 mm
- No AF capability



RLA

Prototype IIb / MONOCROM

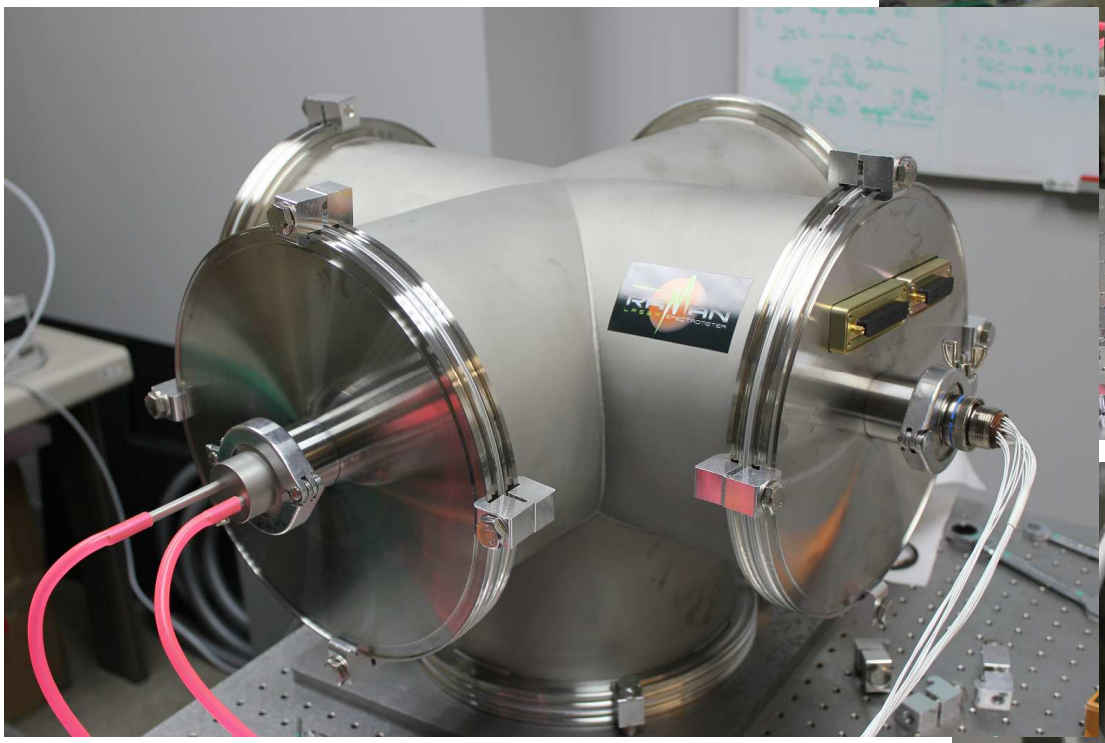
- Output power: ~ 50mW
- Ring mode performance
- AF diode

OH

COMMERCIAL / Thorlabs

- FC/APC-FC/APC patchcords; 50 µm core, NA 0.22

STEP 2

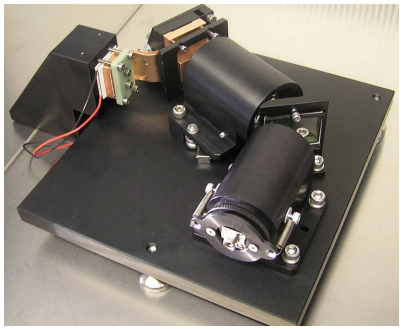


TRL5 STEP3-4

SPU

KOSI SPECTROMETER / COMMERCIAL

- Optics: FM Like
- Grating: FM Like, simple transmission



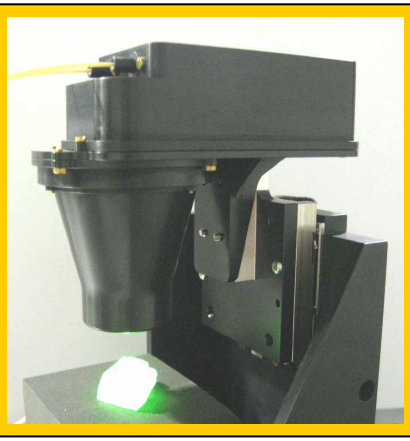
CCD BB2 / Leicester University

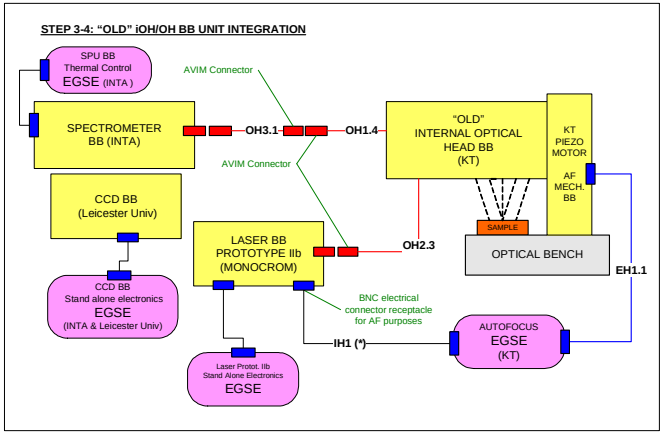
- 2048x512 pixels, 15 µm pixel (TBC)
- IMO; Back Illuminated (TBC)
- -10ºC operated
- SW for spectrum obtaining

iOH

Old iOH BB / KAYSER THREDE

- Optics old design; NA 0.22
- AVIM connectors
- Ring mode required
- Focal Length: 25 mm
- AF capability





RLA

Prototype IIb / MONOCROM

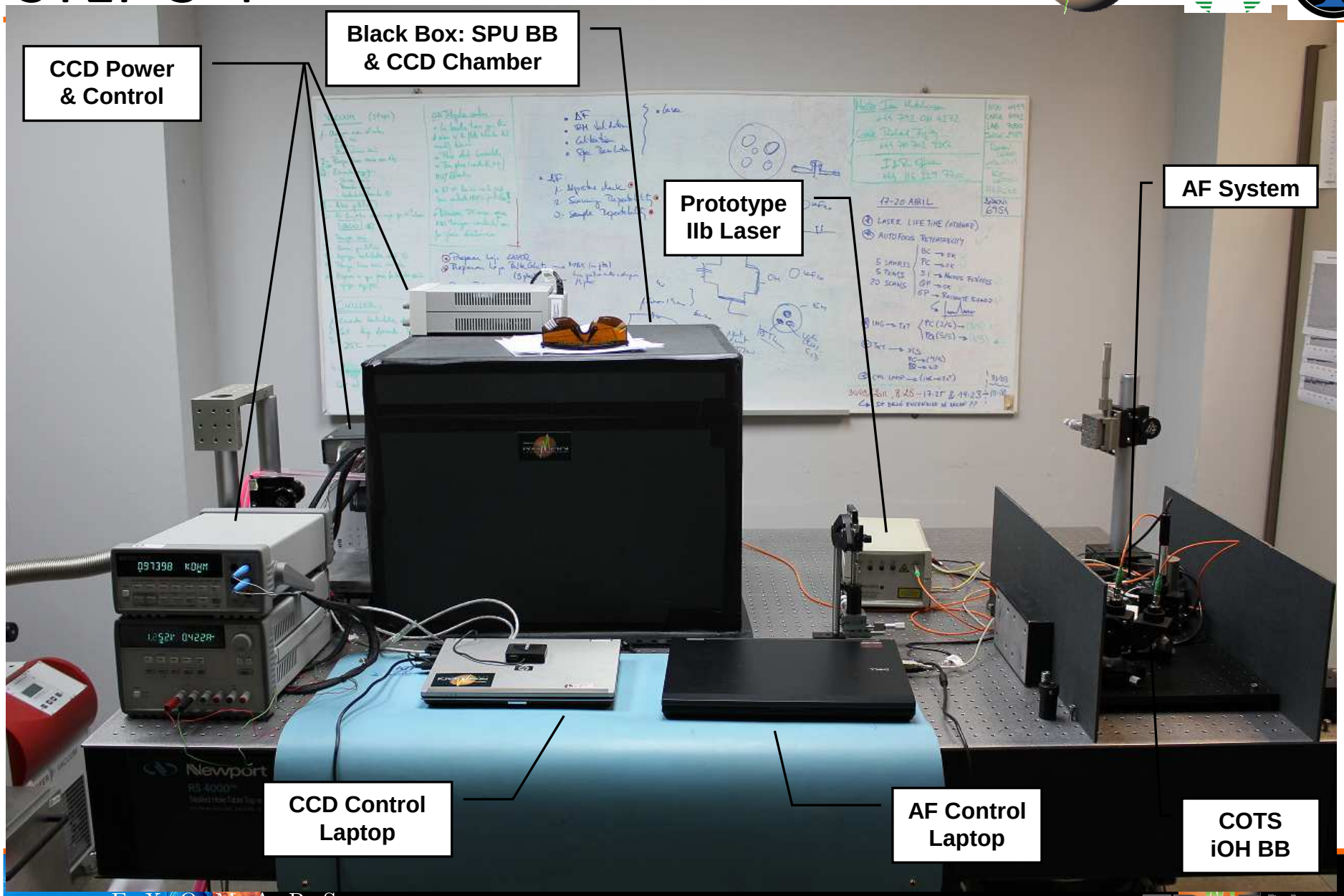
- Output power: ~ 50mW
- Ring mode performance
- AF diode

OH

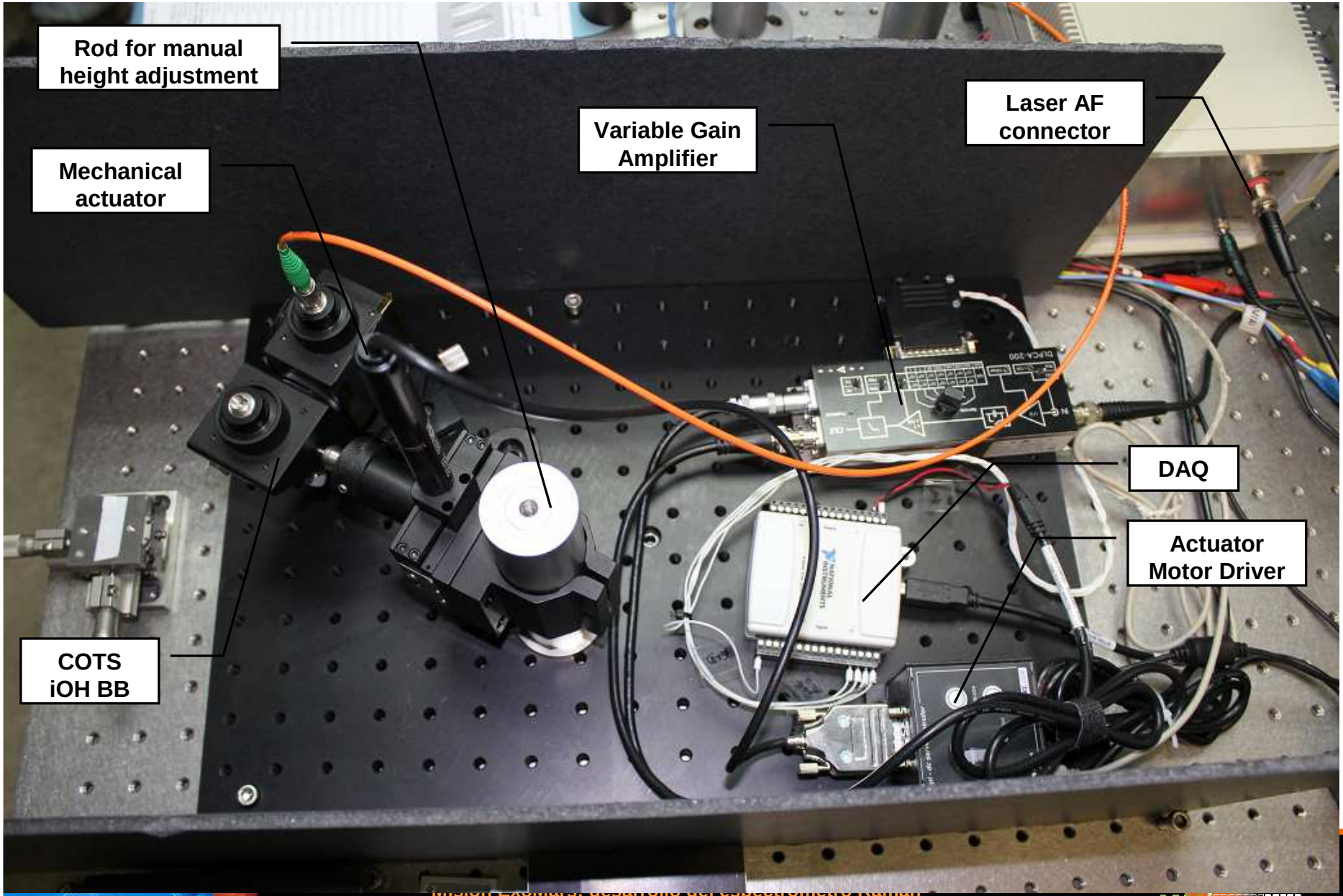
COMMERCIAL (Diamond) / KAYSER THREDE

- AVIM-FC/APC patchcords; 50 µm core, NA 0.22

STEP 3-4


CCD Power & Control
Black Box: SPU BB & CCD Chamber
Prototype IIb Laser
AF System
CCD Control Laptop
AF Control Laptop
COTS iOH BB

AF

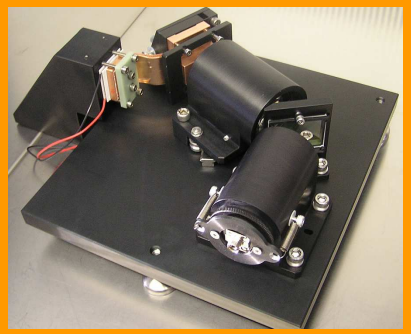

Rod for manual height adjustment
Mechanical actuator
COTS iOH BB
Variable Gain Amplifier
Laser AF connector
DAQ
Actuator Motor Driver

TRL5 STEP5-6

SPU

KOSI SPECTROMETER / COMMERCIAL

- Optics: FM Like
- Grating: FM Like, simple transmission



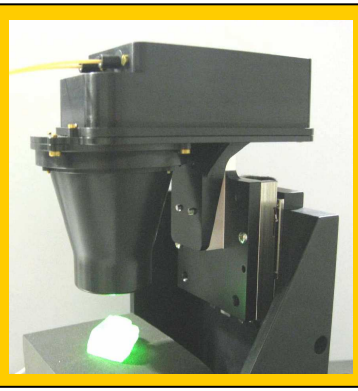
CCD BB3 / Leicester University

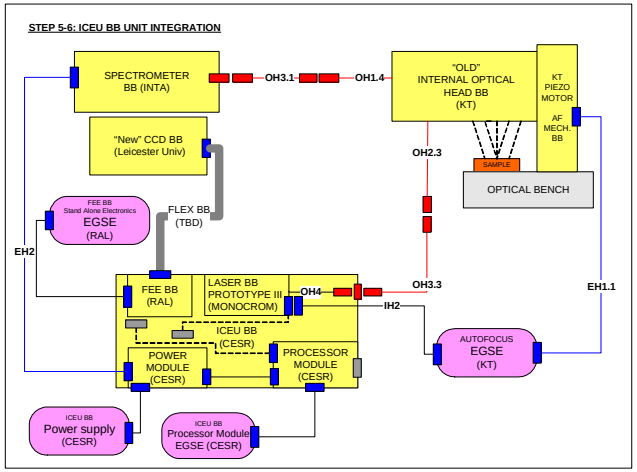
- 2048x512 pixels, 15 µm pixel (TBC)
- IMO; Back Illuminated (TBC)
- -10ºC operated
- Able to check FEE functionality

iOH

Old iOH BB / KAYSER THREDE

- Optics FM representative; NA 0.22
- AVIM connectors
- Ring mode required
- Focal Length: 25 mm
- AF capability





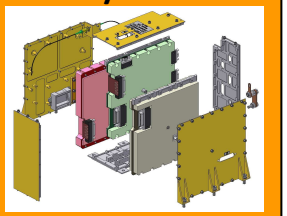
ICEU

Power Board BB / CESR

- FM Like

Processor Board BB / LAB

- FM Like



FEE BB / RAL

- FM Like

RLA Prototype III / Monocrom

- FM Like
- Redundant PD concept
- AF diode
- Bragg grating
- Bump soldering

OH

COMMERCIAL (Diamond) / KAYSER THREDE

- AVIM-FC/APC patchcords; 50 µm core, NA 0.22

EH

Flex BB / Leic.Univ

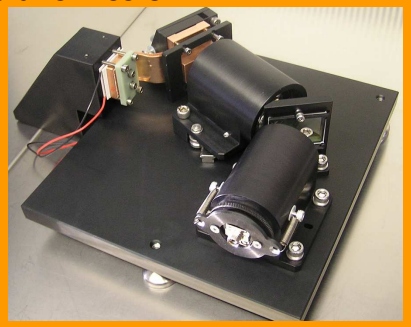
- FM Like

TRL5 STEP7

SPU

KOSI SPECTROMETER / COMMERCIAL

- Optics: FM Like
- Grating: FM Like, simple transmission



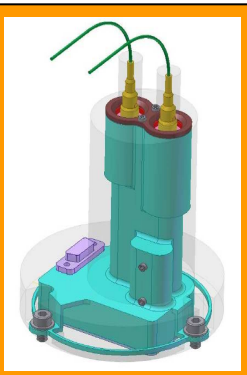
CCD BB3 / Leicester University

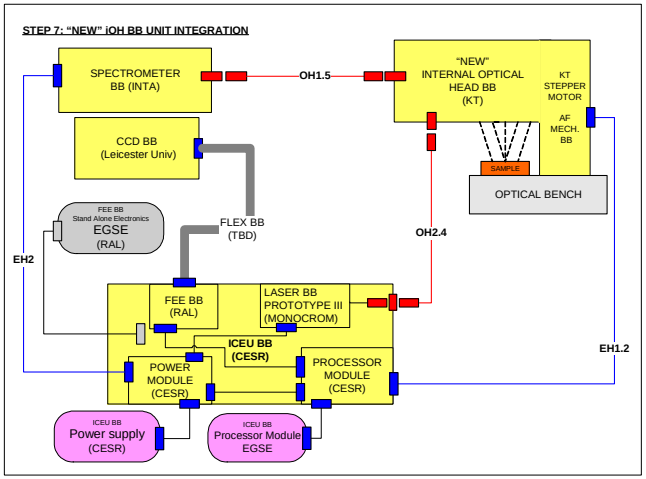
- 2048x512 pixels, 15 µm pixel (TBC)
- IMO; Back Illuminated (TBC)
- -10ºC operated
- Able to check FEE functionality

iOH

New iOH BB / KAYSER THREDE

- FM Like
- Optics FM representative; NA 0.22
- MiniAVIM connectors
- Focal Length: 14 mm
- AF capability





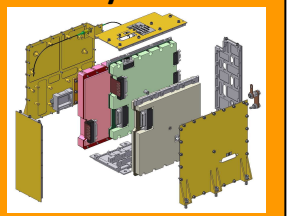
ICEU

Power Board BB / CESR

- FM Like

Processor Board BB / LAB

- FM Like



FEE BB / RAL

- FM Like

RLA Prototype III / Monocrom

- FM Like
- Redundant PD concept
- AF diode
- Bragg grating
- Bump soldering

OH

OH BB / KAYSER THREDE

- FM Like
- MiniAVIM-MiniAVIM patchcords; 50 µm, NA 0.22

EH

Flex BB / Leic.Univ

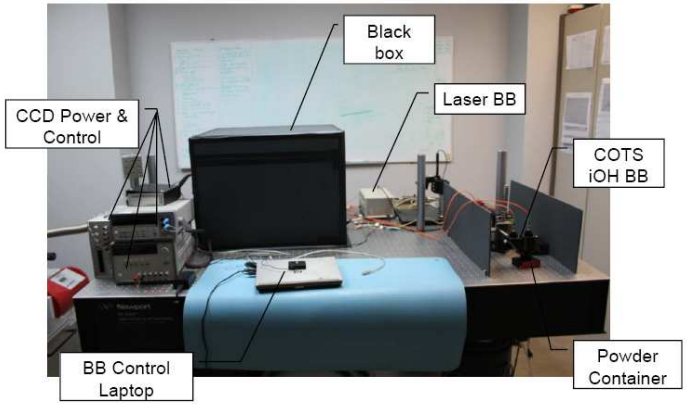
- FM Like

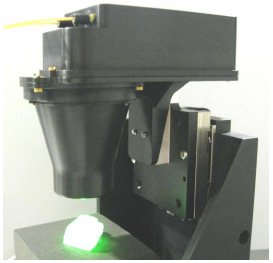
RLS: Estado de desarrollo tecnológico

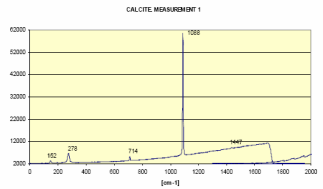
LOGROS DE DESARROLLO TECNOLÓGICO EN ESPAÑA

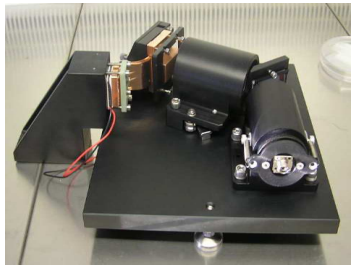
Desarrollo de del instrumento de forma incremental partiendo de una cadena comercial

- **Prototipo comercial del instrumento integrado y probado en el INTA; cabezal integrado y probado en INTA**
  - **Procedimientos de verificación establecidos. Se irán incorporando al prototipo comercial los prototipos de las unidades – avance fase C/D**
- **Prototipo del espectrómetro fabricado, integrado y en proceso de prueba, habiéndose obtenido resultados muy satisfactorios hasta el momento**
- **Prototipo de laboratorio del láser con en el nuevo diseño ya ha sido probado; los Prototipos del Láser que se integrarán en el instrumento y se serán sometidos a pruebas de validación están en proceso de fabricación**
- **Programa de validación de redes de transmisión: se han pasado de forma satisfactoria los ensayos más críticos, entorno de radiación y entorno térmico; con esto queda demostrada su viabilidad para espacio**







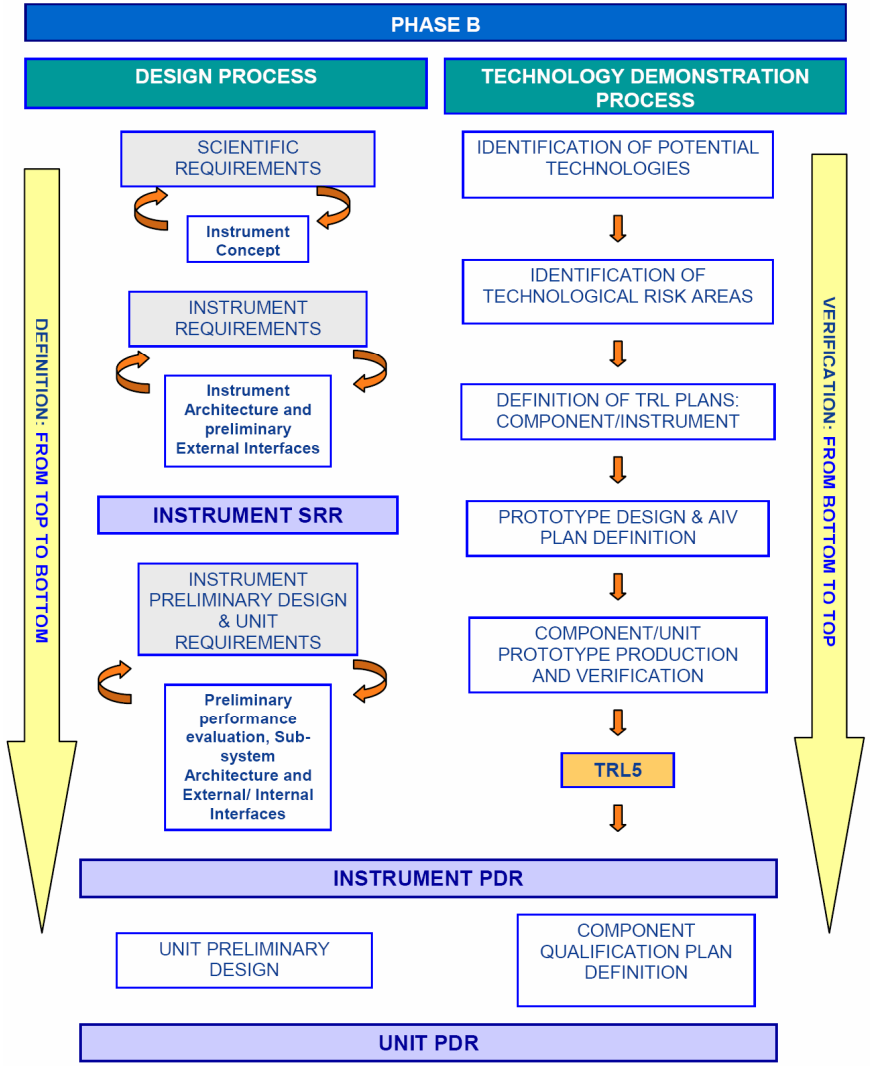


RLS: Problemas

PROCESO DE DISEÑO FASE B

Cada cambio de concepto del instrumento supone una iteración del proceso de Diseño Fase B desde la definición de los requisitos científicos

Cuanto más avanzado esté el proceso de Fase B en el momento de la re-definición mayor es el esfuerzo asociado a realizar una nueva iteración

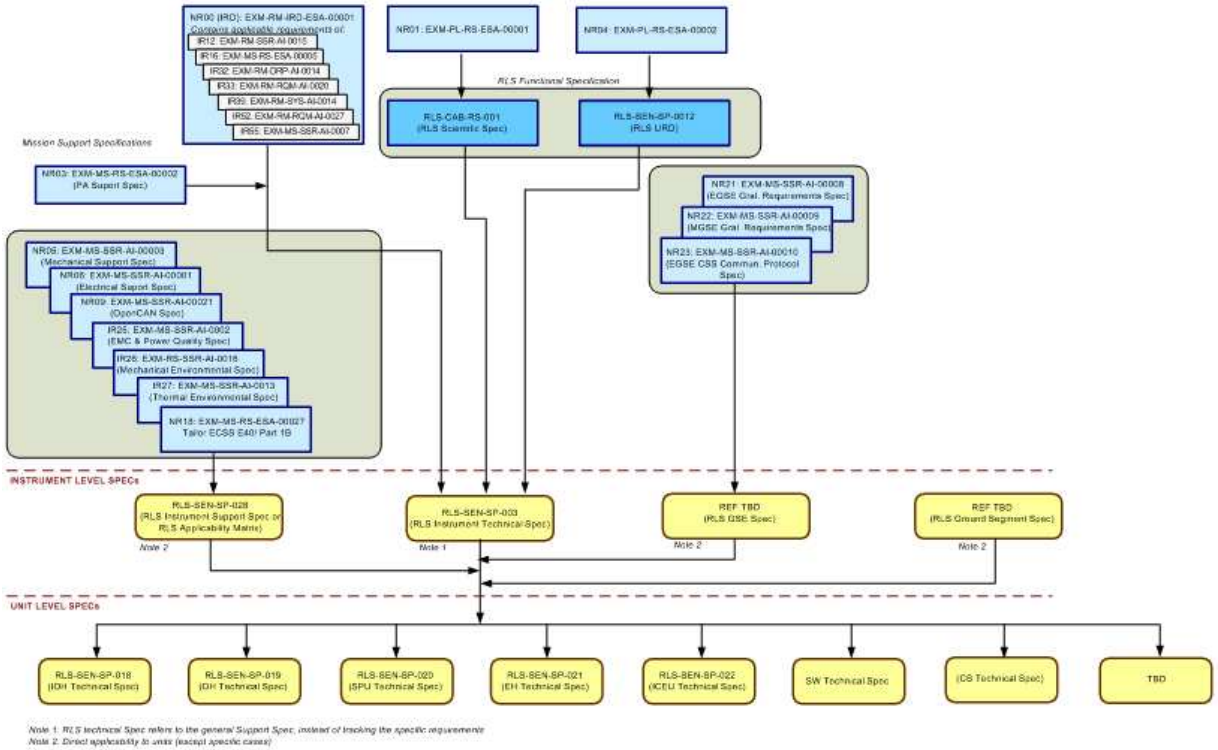


PROCESO DE DEMOSTRACIÓN TECNOLÓGICA FASE B

Si el nuevo concepto utiliza las mismas tecnologías, las modificaciones pueden afectar o no a los niveles más avazados (prototipos de unidades)

Si el nuevo concepto utiliza nuevas tecnologías, hay que empezar un programa de validación de la misma desde el principio

RLS: Problemas



Documentos aplicables ExoMars

- **IRD Issue 7.0**
  29 Documentos aplicables e informativos que contienen requisitos
- **Estimación de requisitos**
  3.300 requisitos para trazar

INCORPORAR NUEVOS REQUISITOS DEL ROVER

- **Estructura de requisitos de Exomars es inexistente**
- **Los documentos de requisitos cambian sin previo aviso y los suben en el servidor de ExoMars sin anunciar**
- **Requisitos repetidos**
- **Documentos que desaparecen y aparecen nuevos**
- **Desde que se inició la fase B extendida se han recibido 3 ediciones del IRD (y documentos aplicables asociados) y hasta D-PDR se enviarán otras 2 (según noticias de la ESA) = 5 ediciones en año y medio, es decir aproximadamente cambia cada 4 meses**
- **El coste industrial del instrumento asociado a estos cambios es importante**