High spectral resolution exploration of Jupiter and its Icy Moons with the Submillimetre Wave Instrument of ESA JUICE Planetary Mission

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Jupiter Icy moons Explorer
Submillimeter Wave Instrument

PI Paul Hartogh, MPS, Goëttingen, GE

- JUpiter Icy moons Explorer, first ESA Large mission of the Cosmic Vision program

- SWI to investigate the temperature structure, composition and dynamics of Jupiter's stratosphere and troposphere, and the exospheres and surfaces of the icy moons, with high spectral resolution (10^7) and high frequency accuracy and stability (10^8)

- Proposal in October 2012 with two frequency bands: 530-625GHz and 1080-1275GHz.
  Frontends by Jet Propulsion Laboratory (NASA) & LERMA

- Proposal approved by ESA in 2013 with 2 channels at 530-625GHz after the withdrawal of JPL due to lack of funding

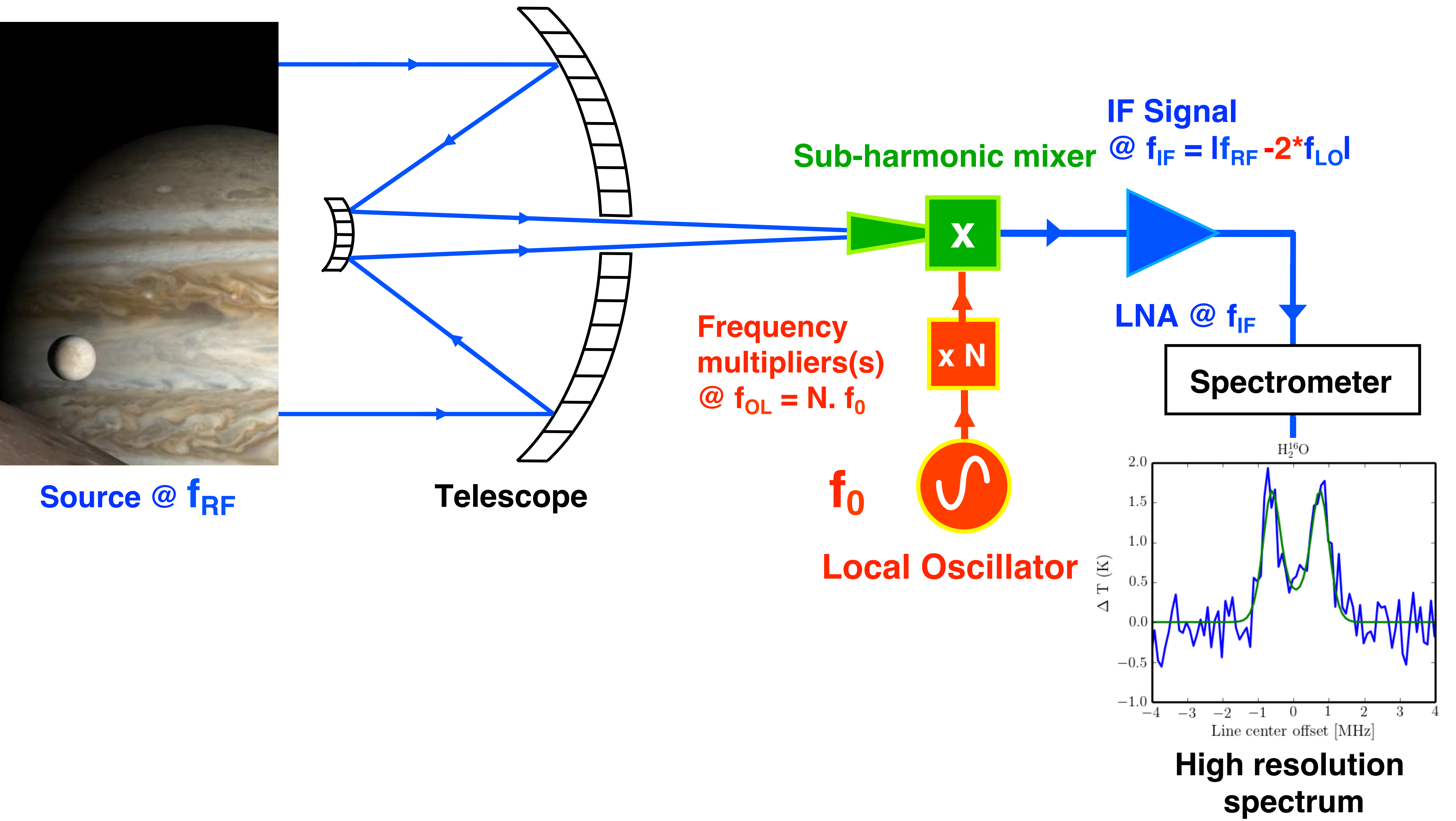
- SWI 1080-1275GHz band back on the baseline since June 2016: LERMA-Observatory in charge of the delivery of the front-end

SWI science traceability matrix (extract)

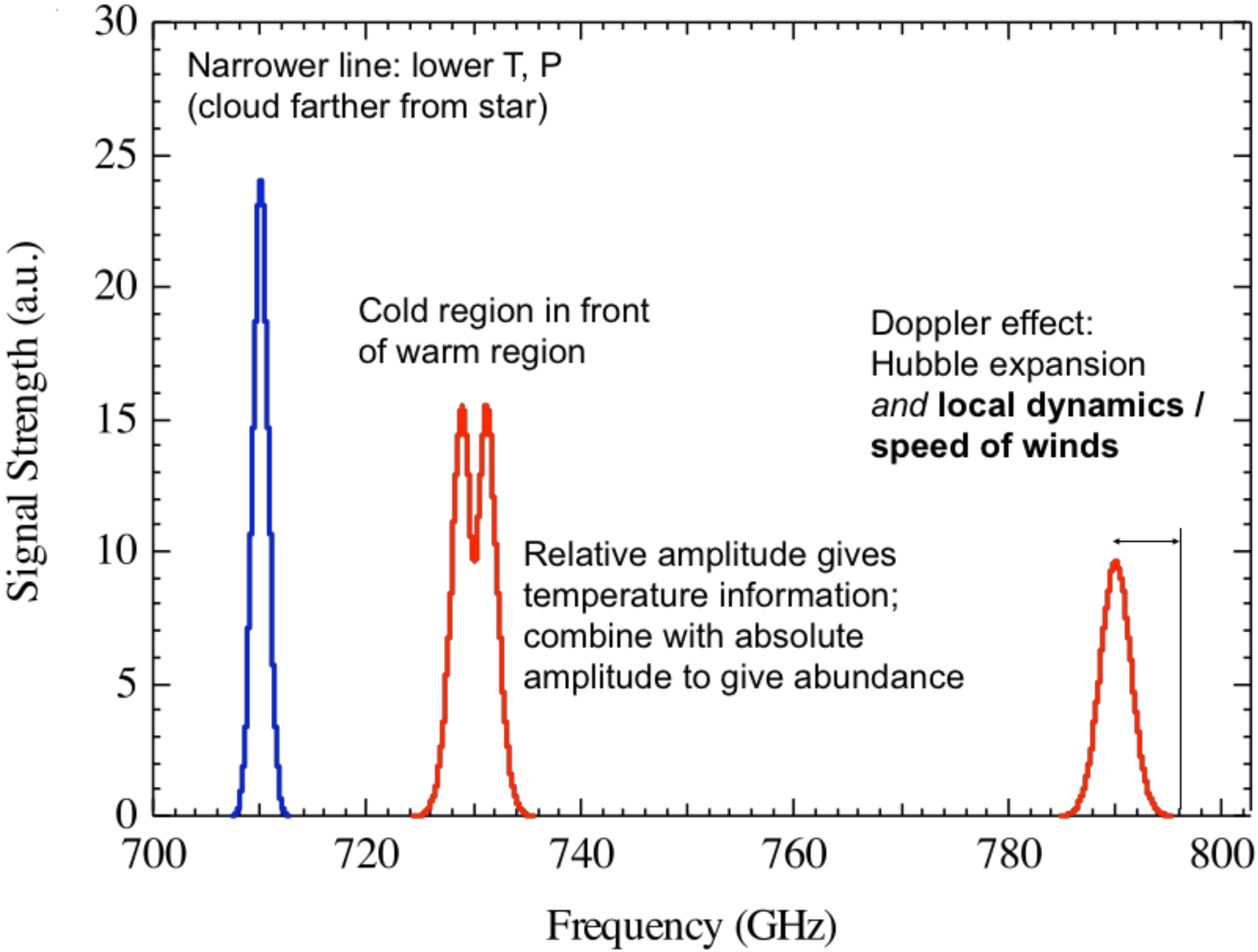
EJSM Science	Science Investigation	SWI Measurement	Instrument Performance Requirement
Jupiter: Characterize the atmospheric dynamics and circulations	Investigate the dynamics of Jupiter's weather layer	Sub-mm spectroscopy to obtain Doppler shifts of molecular lines (HCN, H_2O and CH_4) at a wide range of latitudes and times to derive 5 to 300 mbar temperatures and stratospheric wind speeds with high vertical resolution (20 km/pixel, R>1E7 for line shape, 2-10 m/s accuracy)	1075–1275 GHz receiver, 1 GHz spectrometer bandwidth, 100 kHz resolution, 10 kHz absolute frequency stability, 30 cm antenna, 3000 K DSB Tsys at 1.2THz, 2% absolute calibration accuracy, 0.3% relative calibration accuracy, 10" APE, 2–4"/5min RPE
	Determine the thermodynamics of atmospheric phenomena	Sub-mm determination of threedimensional temperatures from selected atmospheric species between 400 mbars and 1 microbar (HCN, H_2O and CH_4). Better than 3°resolution in latitude, 20°in longitude and 1 scale height in vertical direction, S/N>100 (2min), R>10E6	530–600 & 1075–1275 GHz receivers, 1 GHz bandwidths/100 KHz res. spectrometer , 30 cm antenna, Tsys: 1500 / 3000 K DSB at 550 / 1200 GHz, 2% absolute calibration accuracy.
	Quantify the roles of wave propagation and atmospheric coupling	High spatial resolution determinations of the vertical temperature and wind structure, thermal wave activity and wave forcing between 1 microbar and 400 mbars from sub-mm sounding of molecular lineshapes (R>1E7). (20–40 km vertical resolution), with particular focus on the equatorial QQO.	530–600 & 1075–1275 GHz receivers, 1 GHz bandwidths/100 KHz res., 30 cm antenna, Tsys: 1500 / 3000 K DSB at 550 / 1200 GHz, 2% absolute calibration accuracy , 0.3% relative calibration accuracy, 10" APE, 2–4"/5min RPE
	Understand the interrelationships of the ionosphere and thermosphere	Sub-mm measurements of molecular lines to determine atmospheric temperatures, neutral density profiles and three-dimensional distribution of atmospheric species between 1 μbar and 400 mbars.	530–600 & 1075–1275 GHz receivers, 1 GHz bandwidths/100 KHz res. spectrometer, 30 cm antenna, Tsys: 1500 / 3000 K DSB at 550 / 1200 GHz, 2% absolute calibration accuracy.

Heterodyne detection for high spectral resolution

THz heterodyne detection chain with sub-harmonic mixer



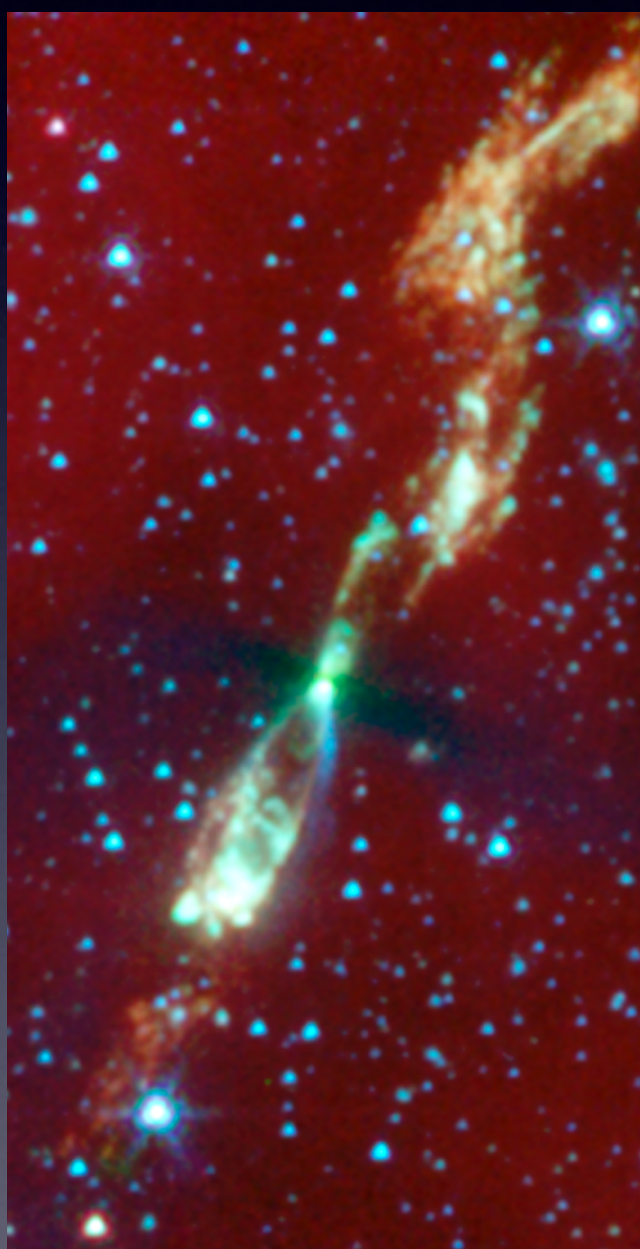
Spectroscopic Information for Large Spectral Resolution ($R \approx 10^6$)



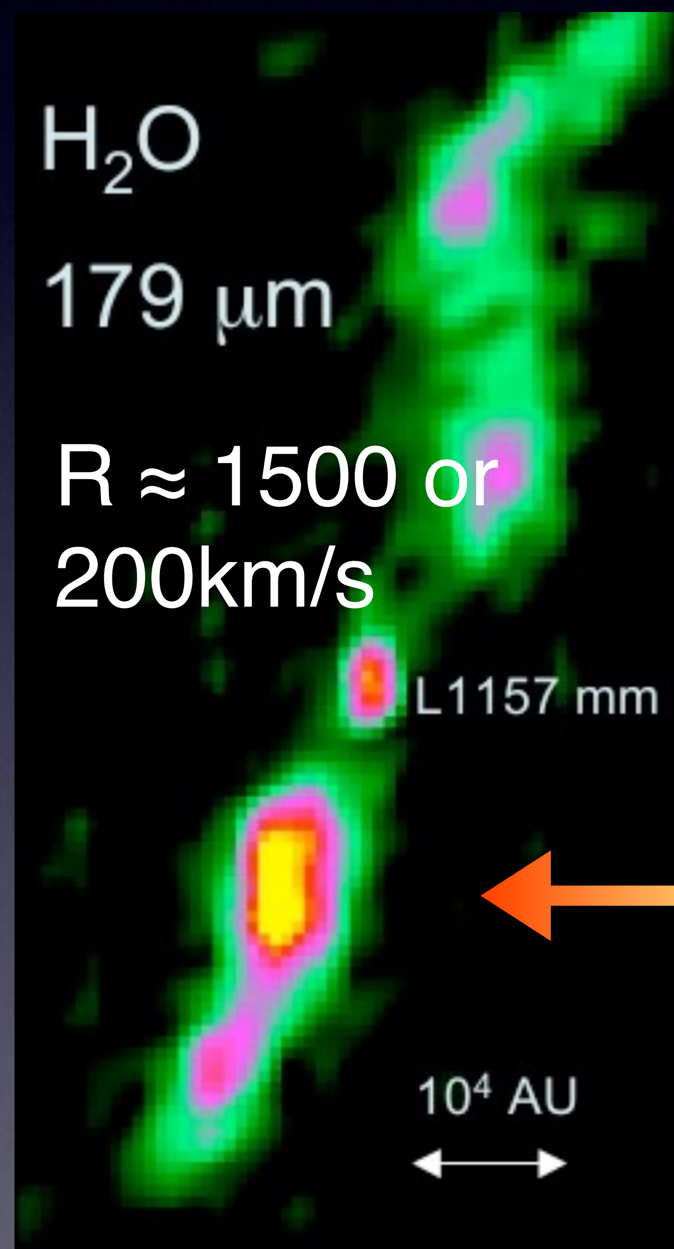
After Michael Gaidis, SWAT - JPL

High Spectral Resolution with Heterodyne instruments

SPITZER (IR)



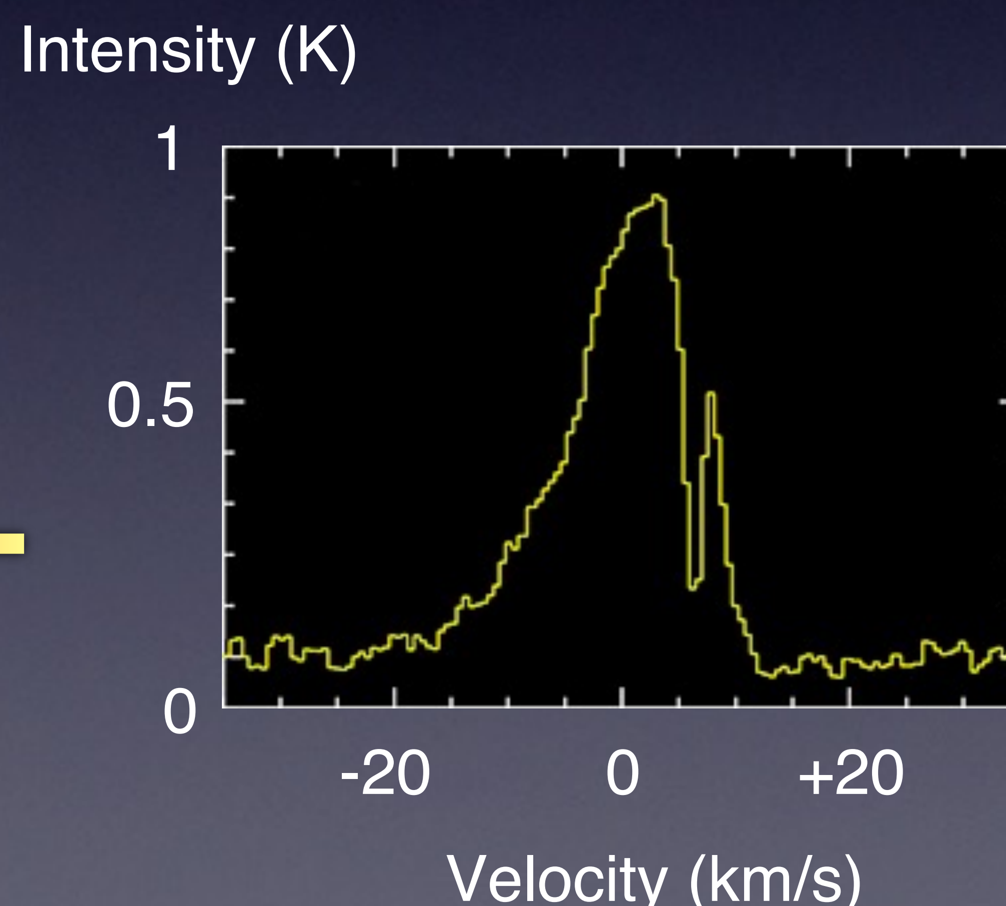
HERSCHEL / PACS



HERSCHEL / HIFI

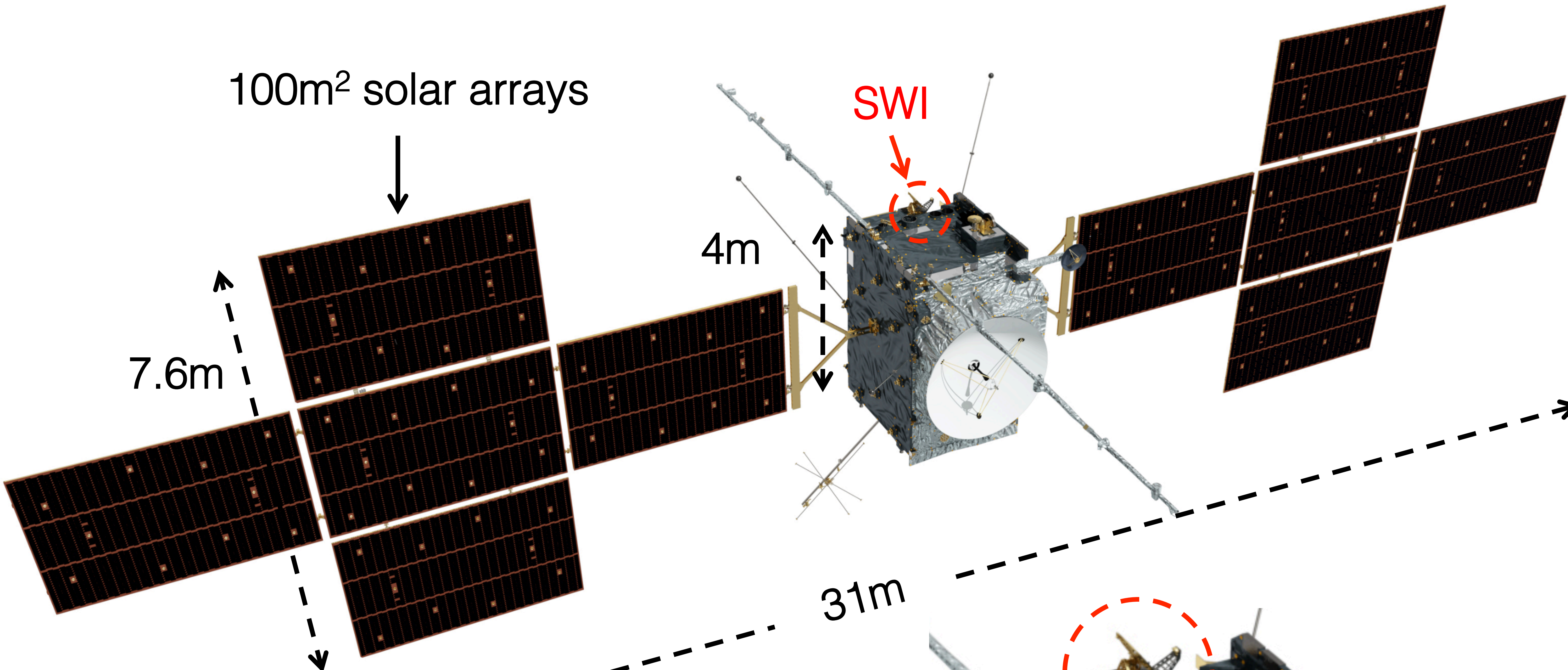
H_20 at 557 GHz

$R \approx 5.5 \times 10^5$ or 0.5km/s

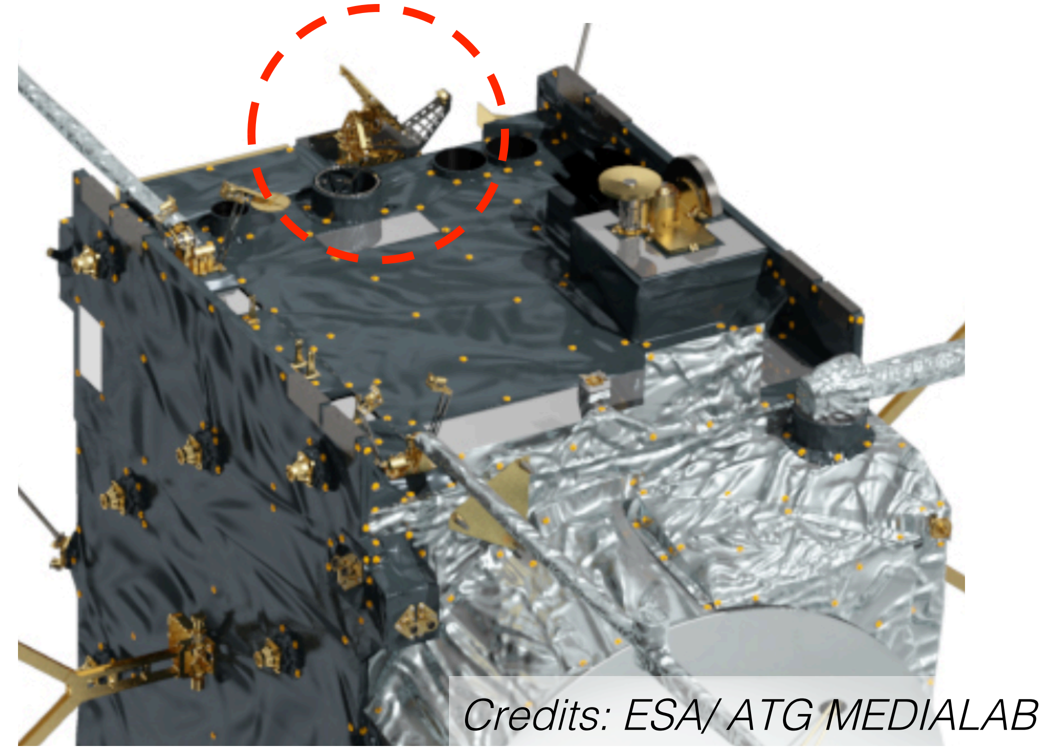


Proto star L1157

Jupiter Icy Moons Explorer spacecraft

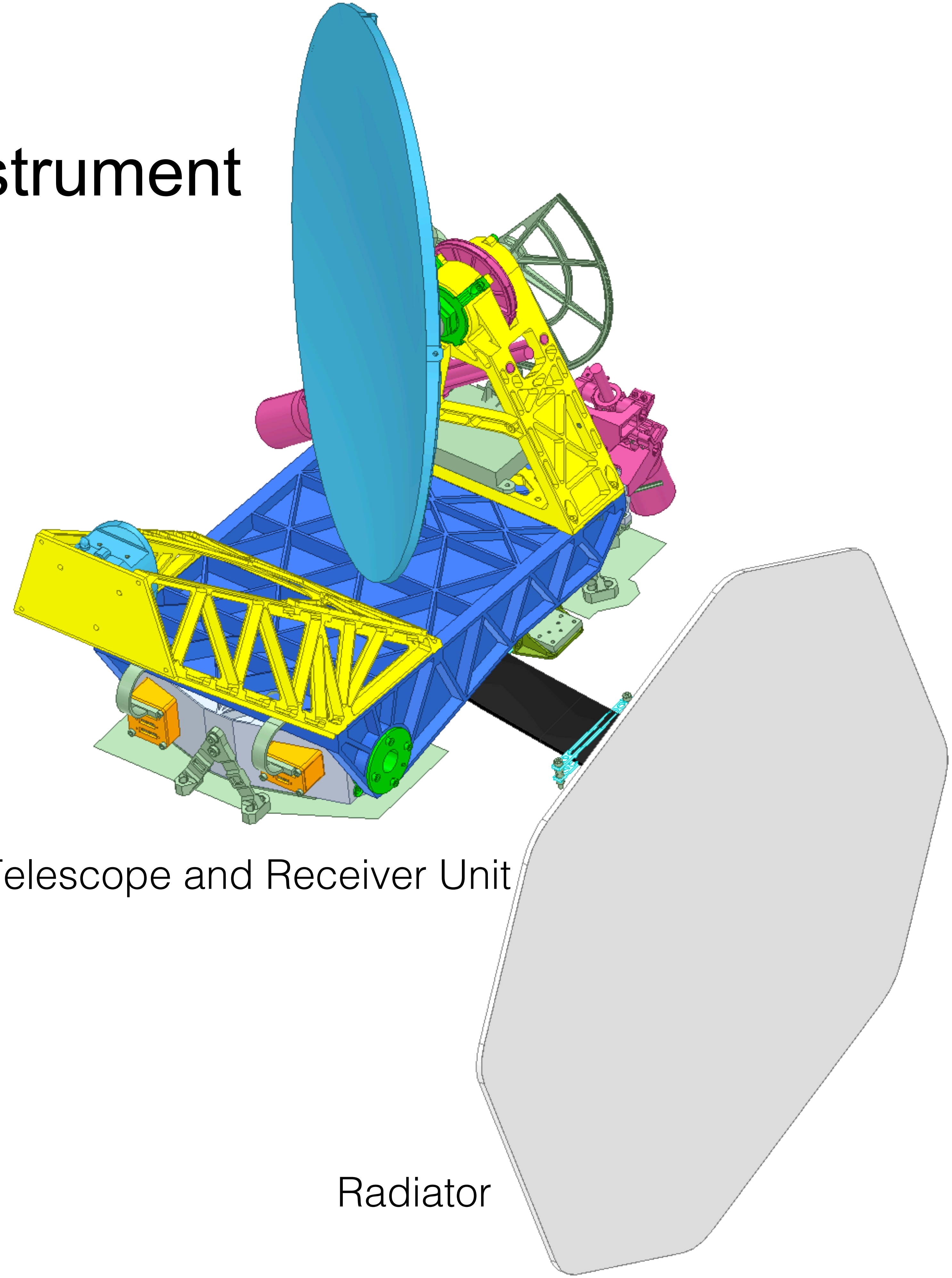


- 5000kg / 900W
- 2700kg propellant
- 280kg / 360W max payload
- 7.6 year flight to Jupiter
- Launch 2022



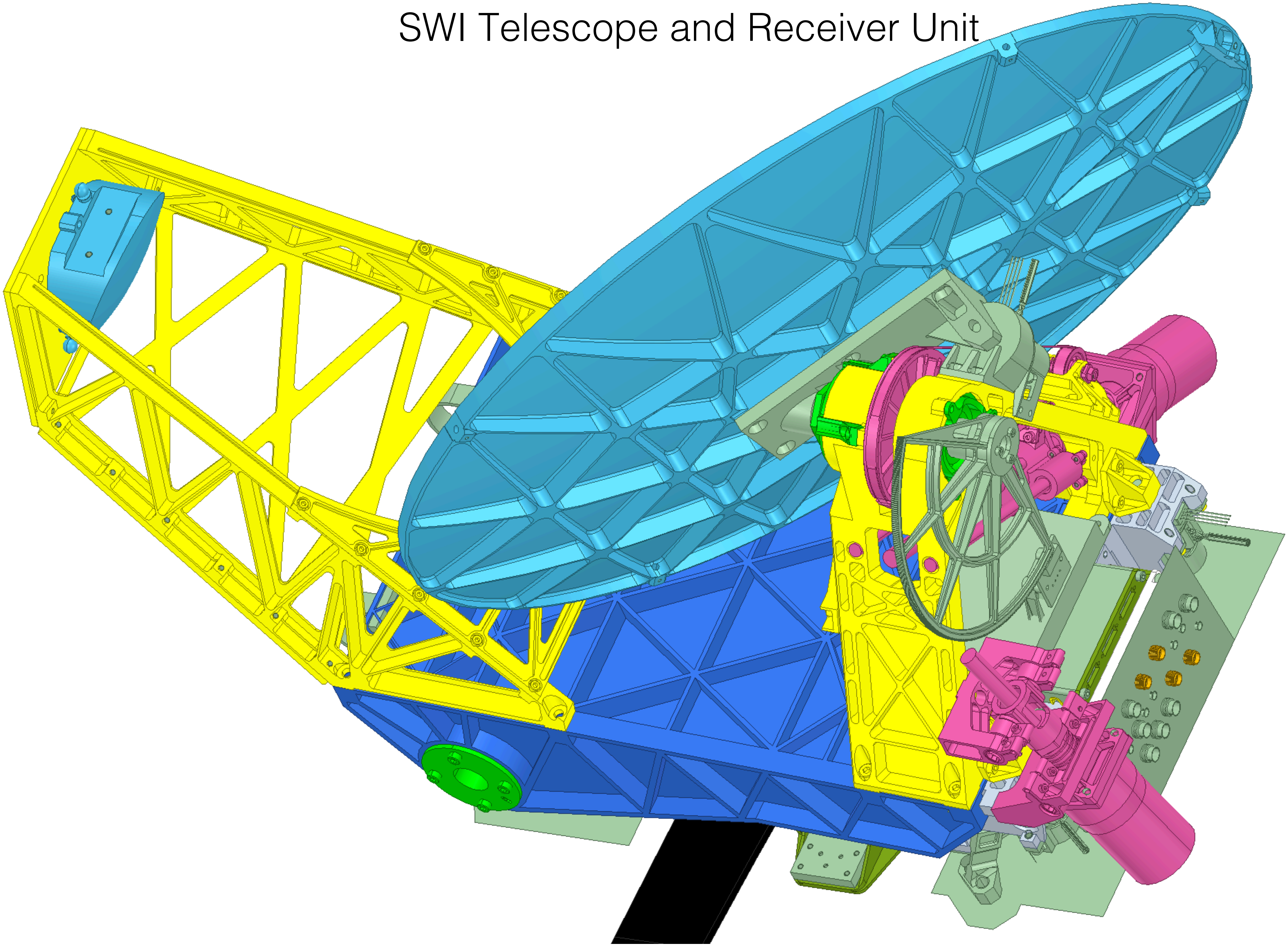
JUICE
Submillimeter Wave Instrument

- 45cm dish @ 45°
  with 2-axis movement
- 2 spectrometers with up to 100KHz resolution
- Front-end operating at 120-150K (high frequency parts) and 240-270K (low frequency parts)
- ~17kg
- ~60W

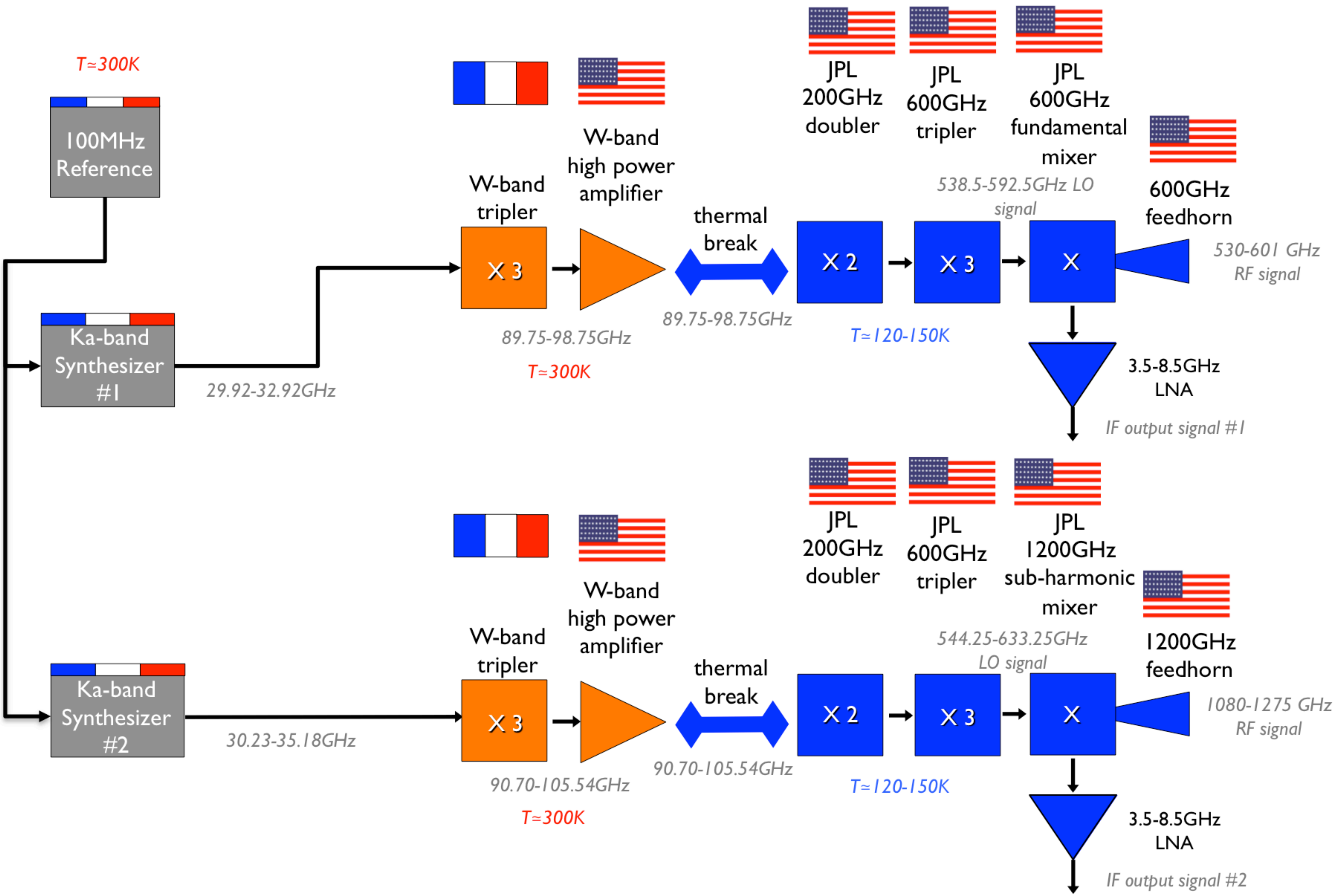


JUICE - Submillimeter Wave Instrument

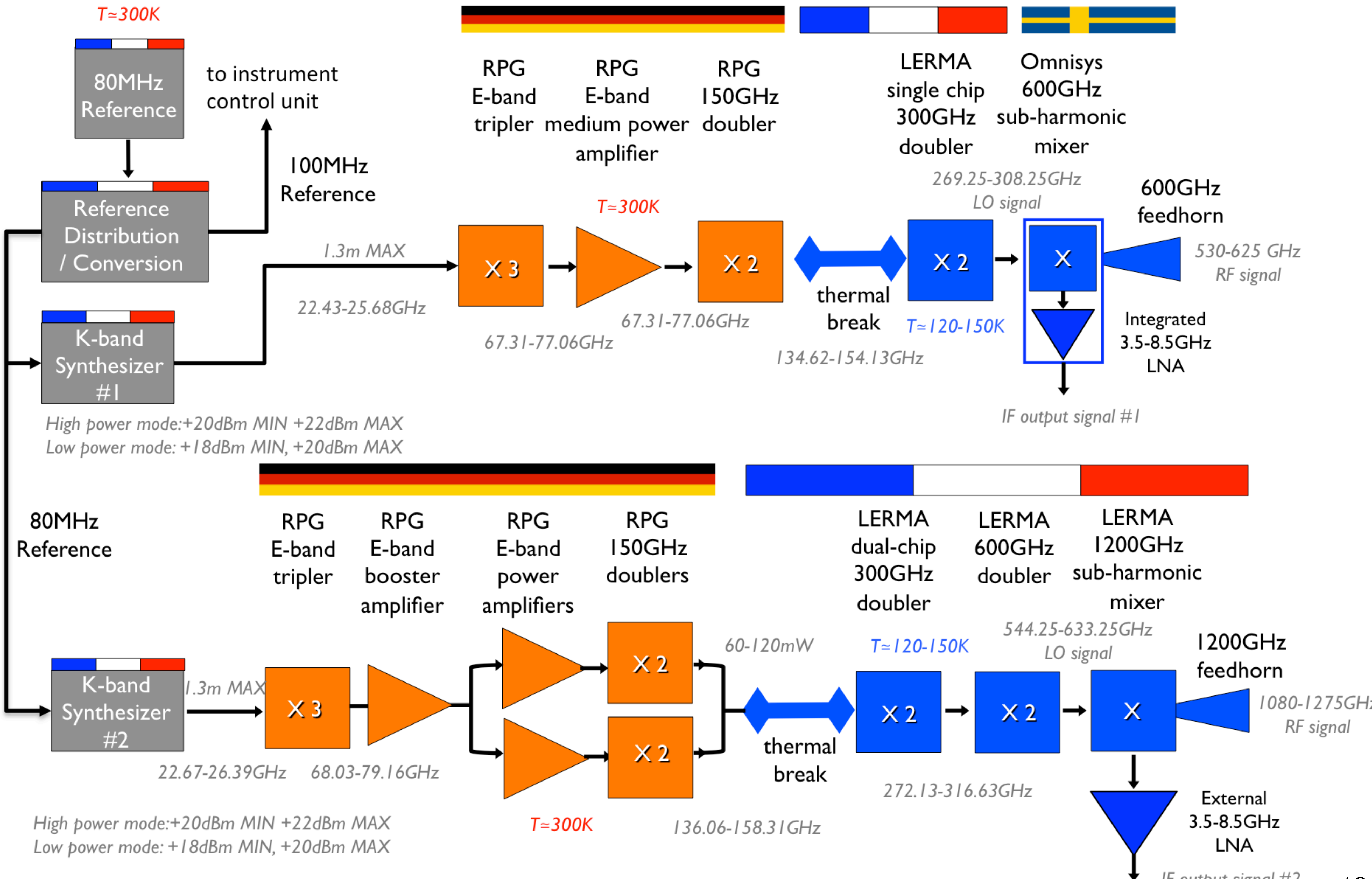
SWI Telescope and Receiver Unit



JUICE-SWI front-end configuration – proposal to ESA Oct-2012

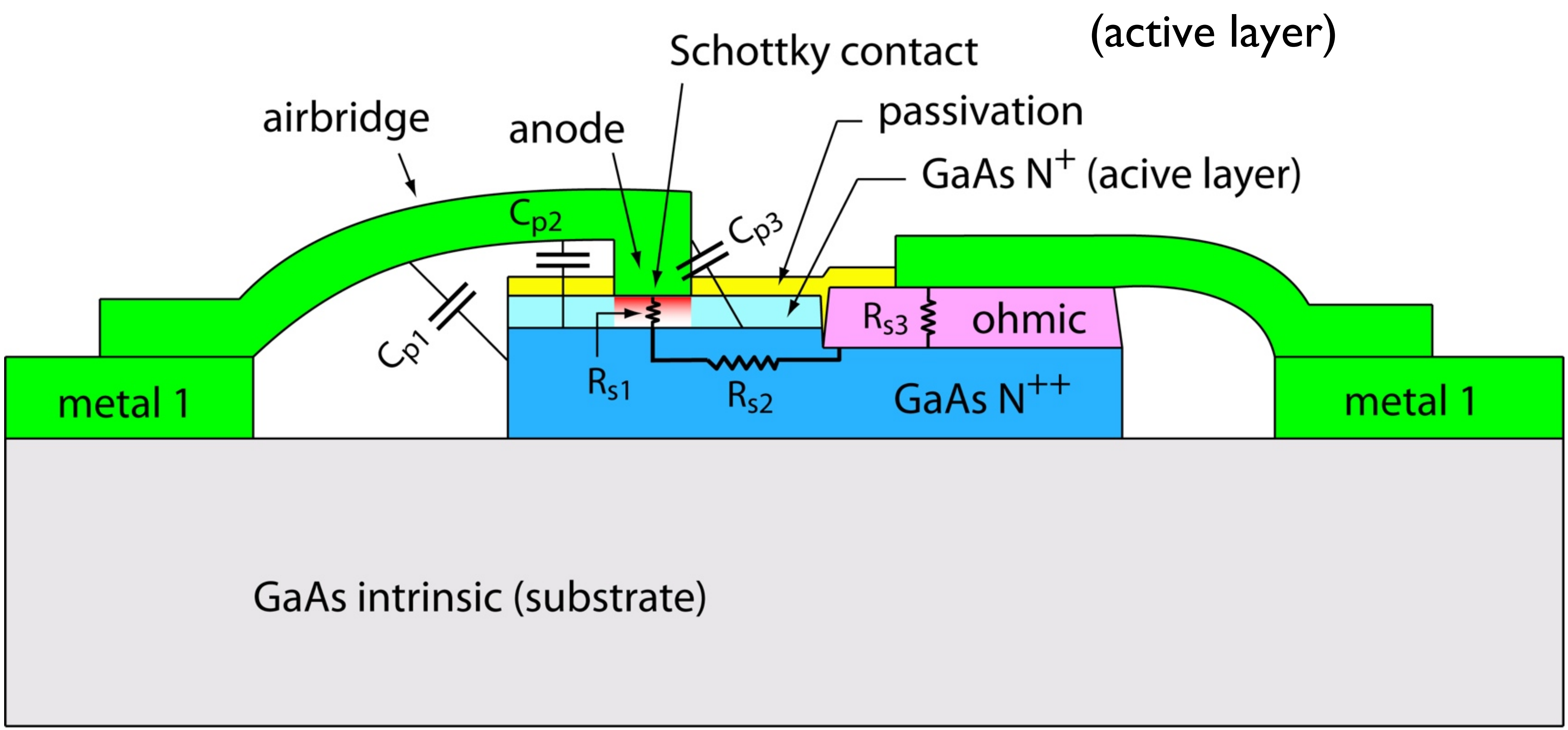


JUICE-SWI baseline front-end configuration

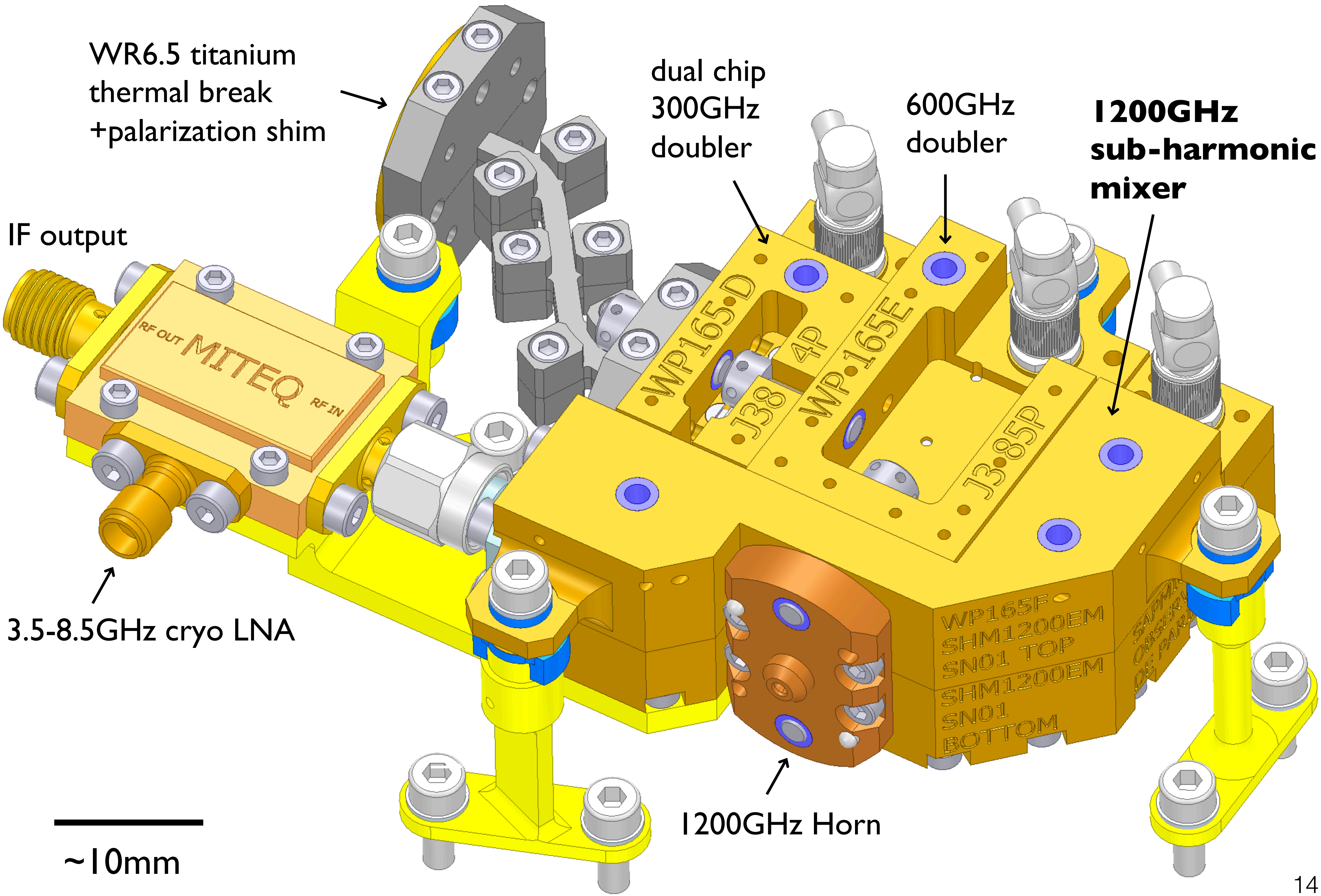


Planar Schottky Diodes with Airbridges

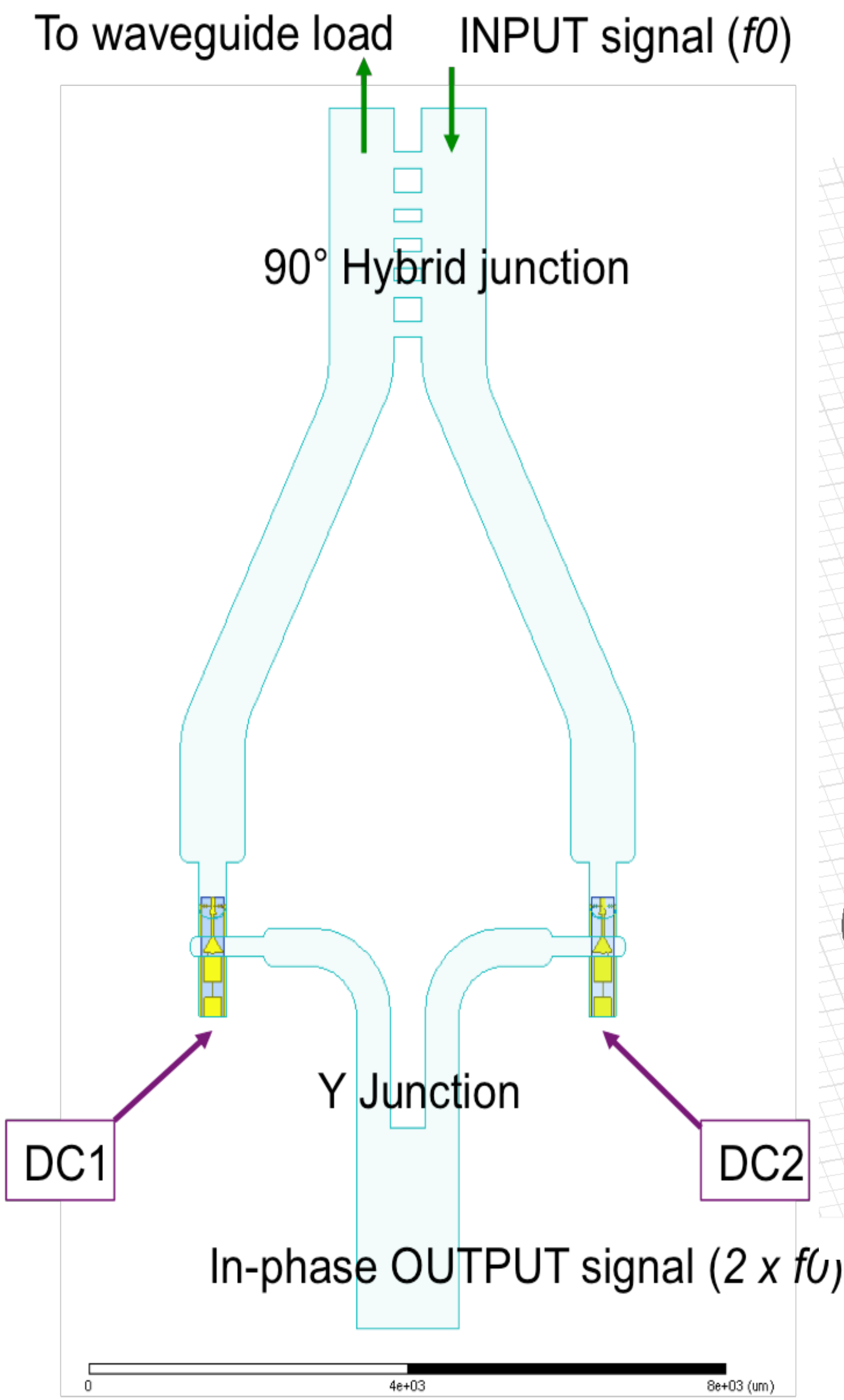
(JPL ~1995, LERMA-LPN 2006)

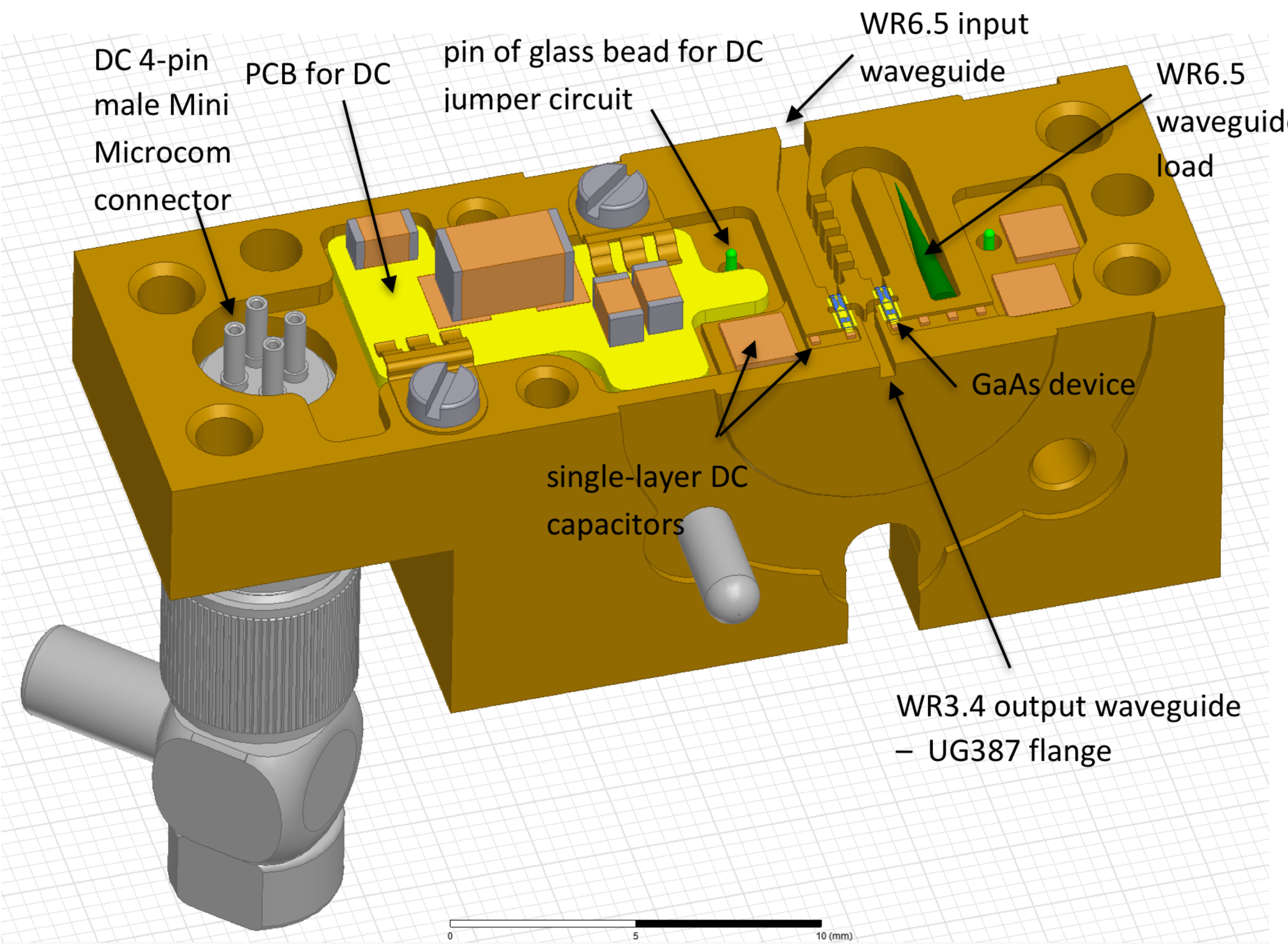


3D model of JUICE-SWI 1200GHz receiver frontend (March-2018)



Power-combined 300GHz frequency doubler-concept



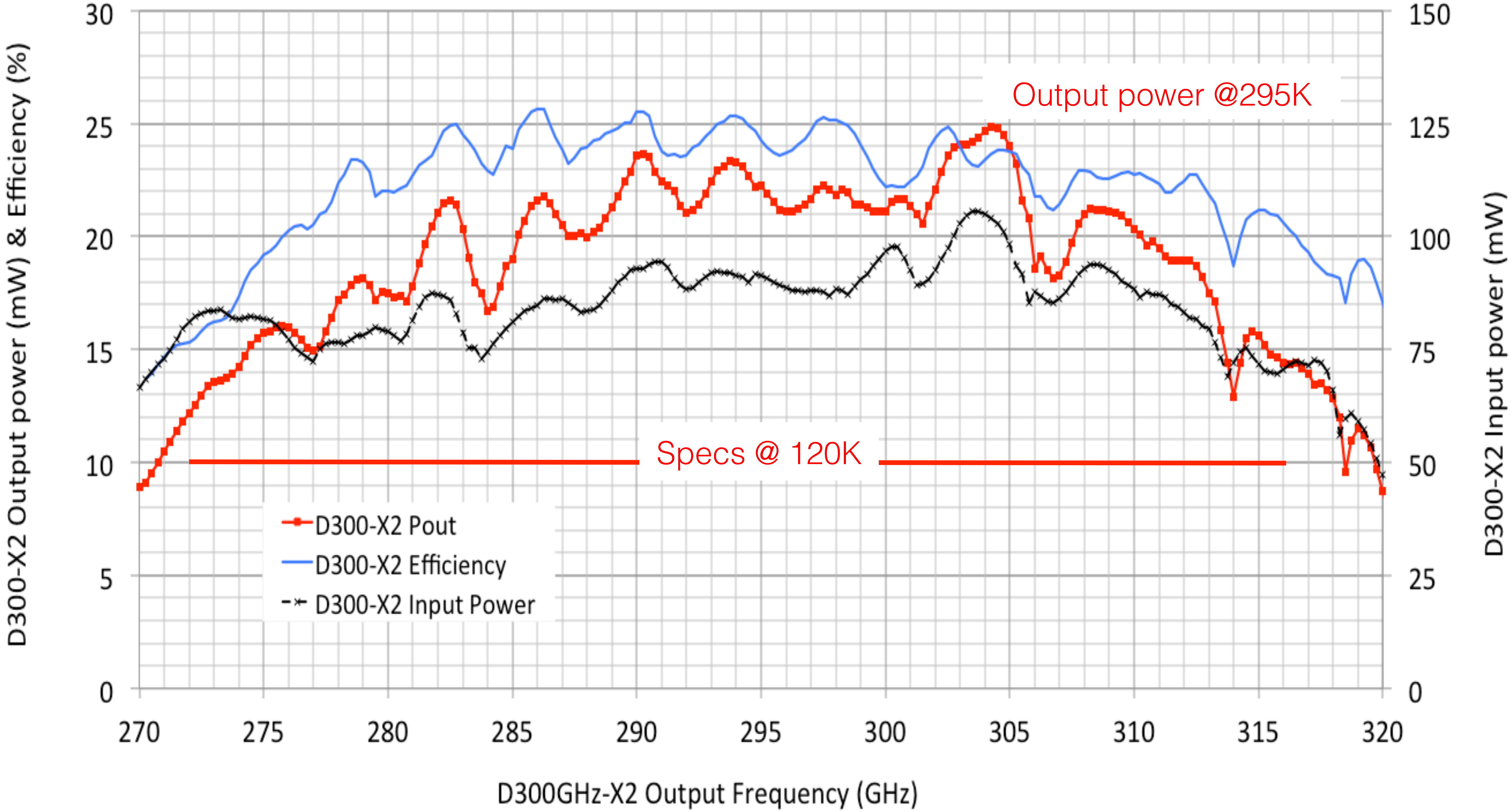


LERMA - OBSERVATOIRE DE PARIS

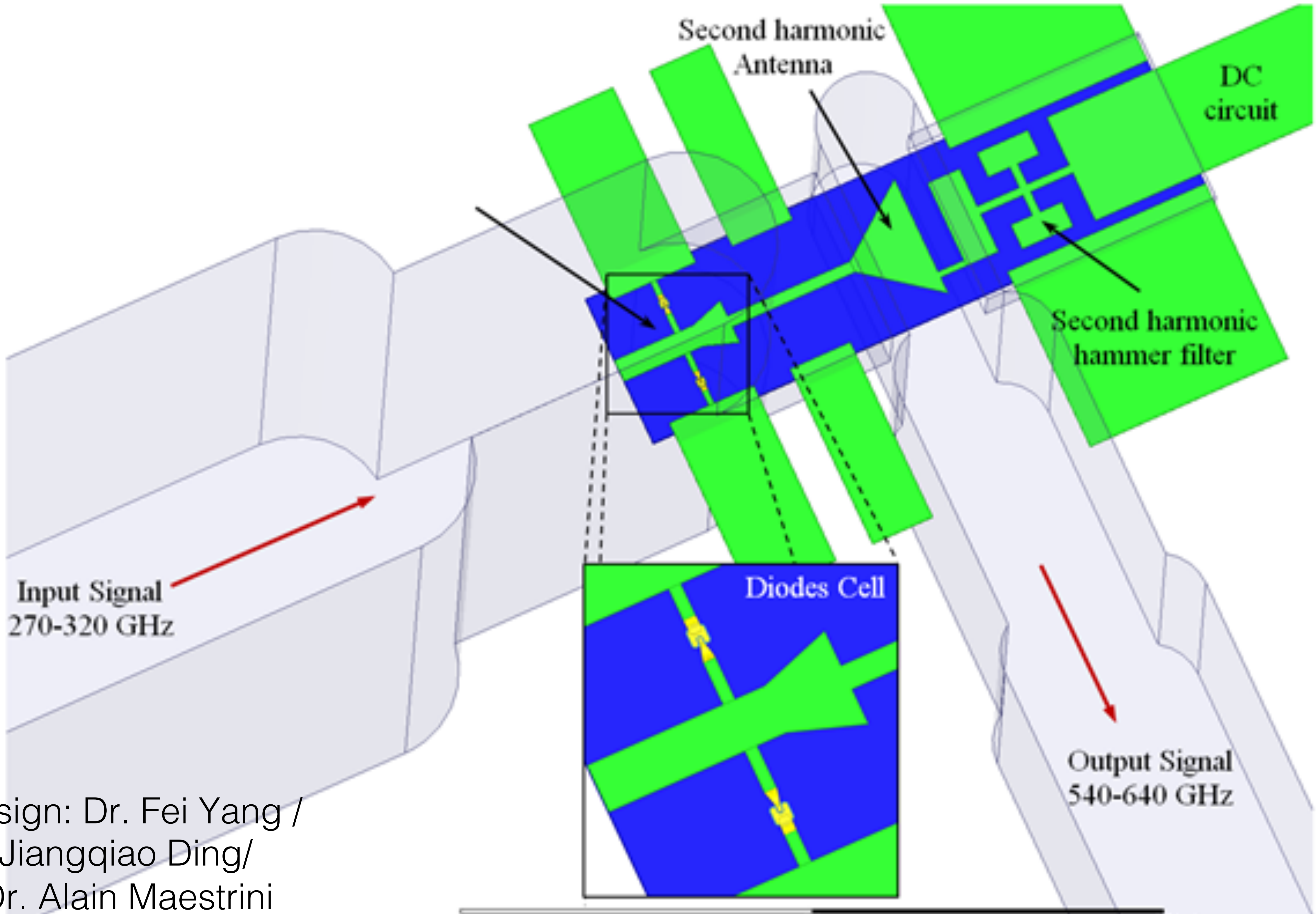
JUICE-SWI Demonstration Model D300-X2 Doubler with RPG DM driver chain for JUICE-SWI 1200GHz channel at Room Temperature

Tested @ LERMA on 11-08 2016 by A. Féret, D. Moro Melgar & A. Maestrini - Troom=21-22°C

Power measurements with VDI-Erickson PM5+WR10 to WR3.4 wgd adapter - Cal Factor=100%

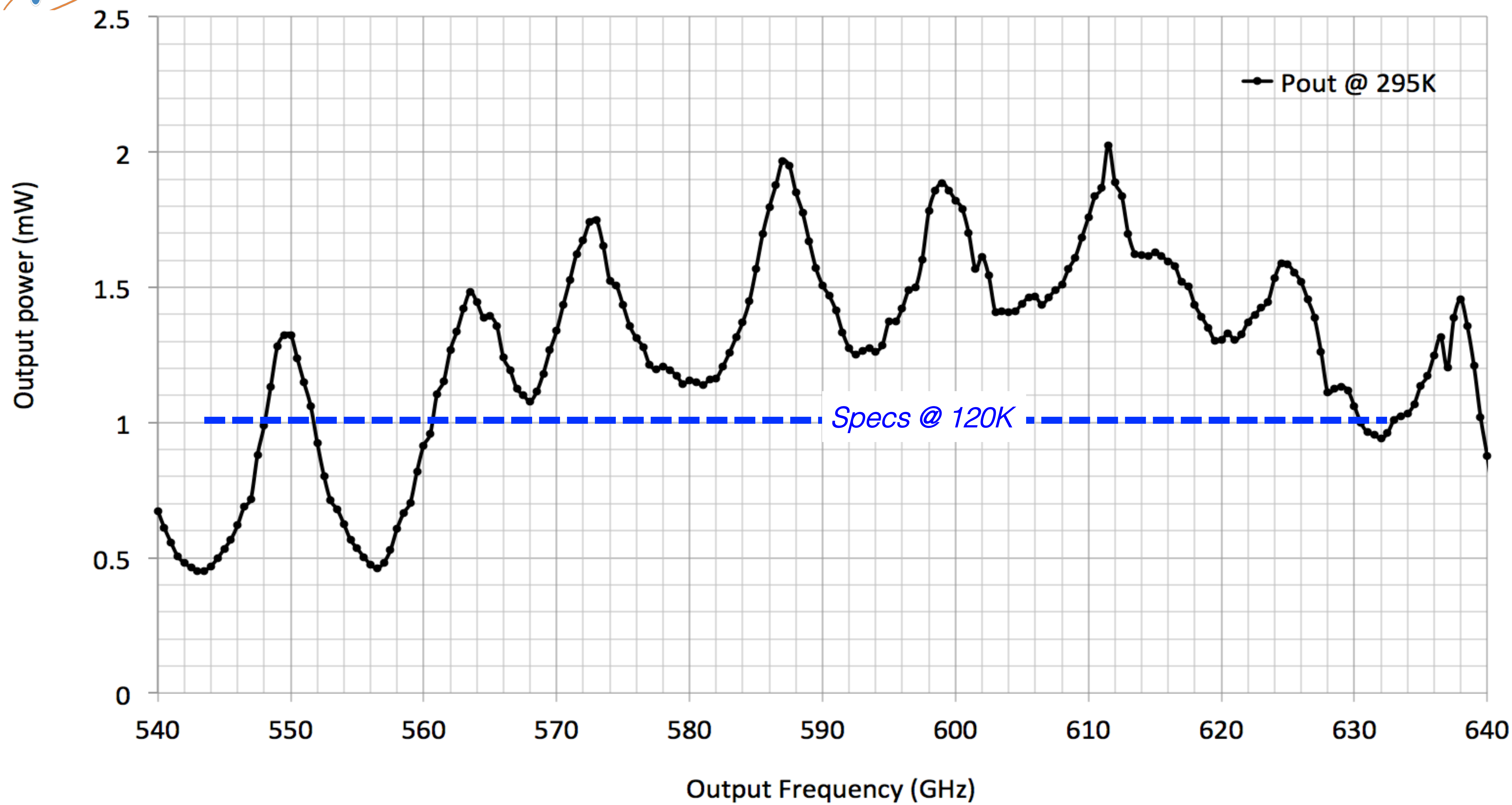


600GHz balanced doubler for JUICE-SWI 1200GHz receiver



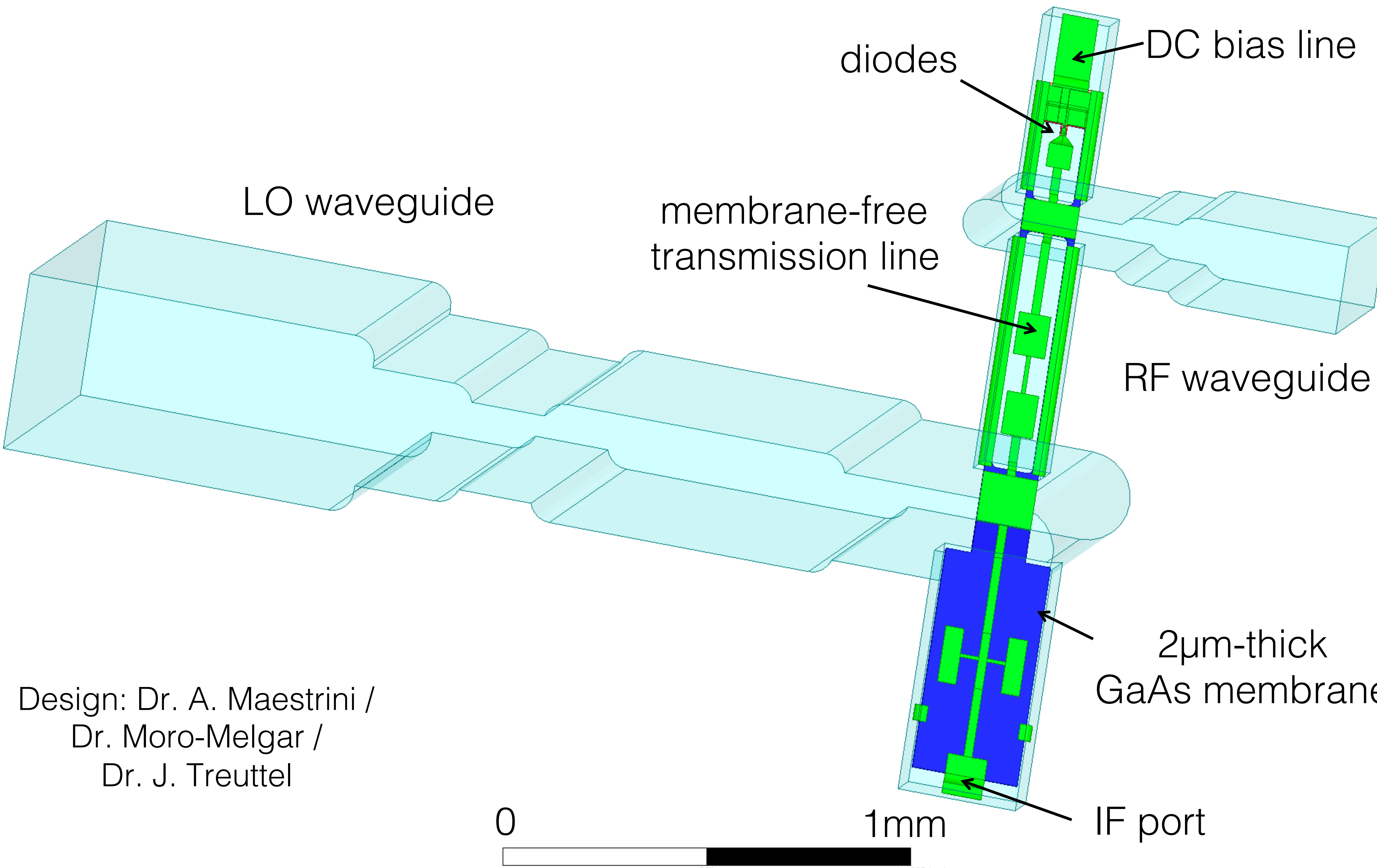
Design: Dr. Fei Yang /
Jiangqiao Ding/
Dr. Alain Maestrini

LERMA - OBSERVATOIRE DE PARIS
JUICE-SWI DM 600 GHz Doubler SN01 with RPG DM driver chain
Tested @ LERMA on 11-08 2016 by A. Féret, D. Moro Melgar & A. Maestrini - Troom=21-22°C
Power measurements with VDI-Erickson PM5+WR10 to WR1.9 wgd adapter - Cal Factor=+0.3dB

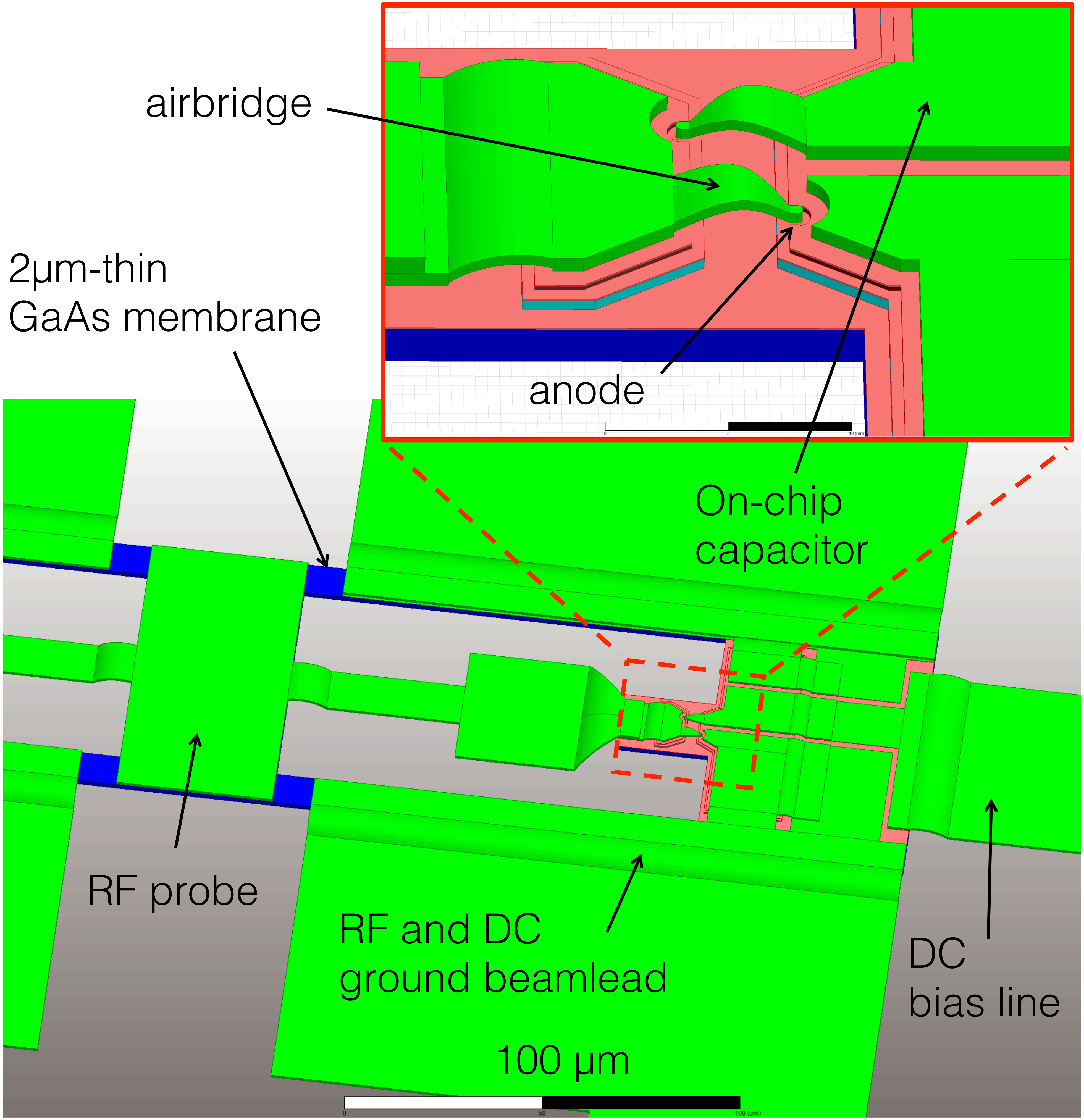


Measured at LERMA May-November 2016

3D model of LERMA 1080-1280GHz sub-harmonic Schottky mixer for JUICE-SWI



Design: Dr. A. Maestrini / Dr. Moro-Melgar / Dr. J. Treuttel


airbridge
2μm-thin
GaAs membrane
anode
On-chip
capacitor
RF probe
RF and DC
ground beamlead
DC
bias line
100 μm

JUICE-SWI SHM 1200GHz flight devices (doping $5^{E}17$ cm^{-3})

LERMA 1080-1280GHz prototype Schottky receiver for JUICE-SWI

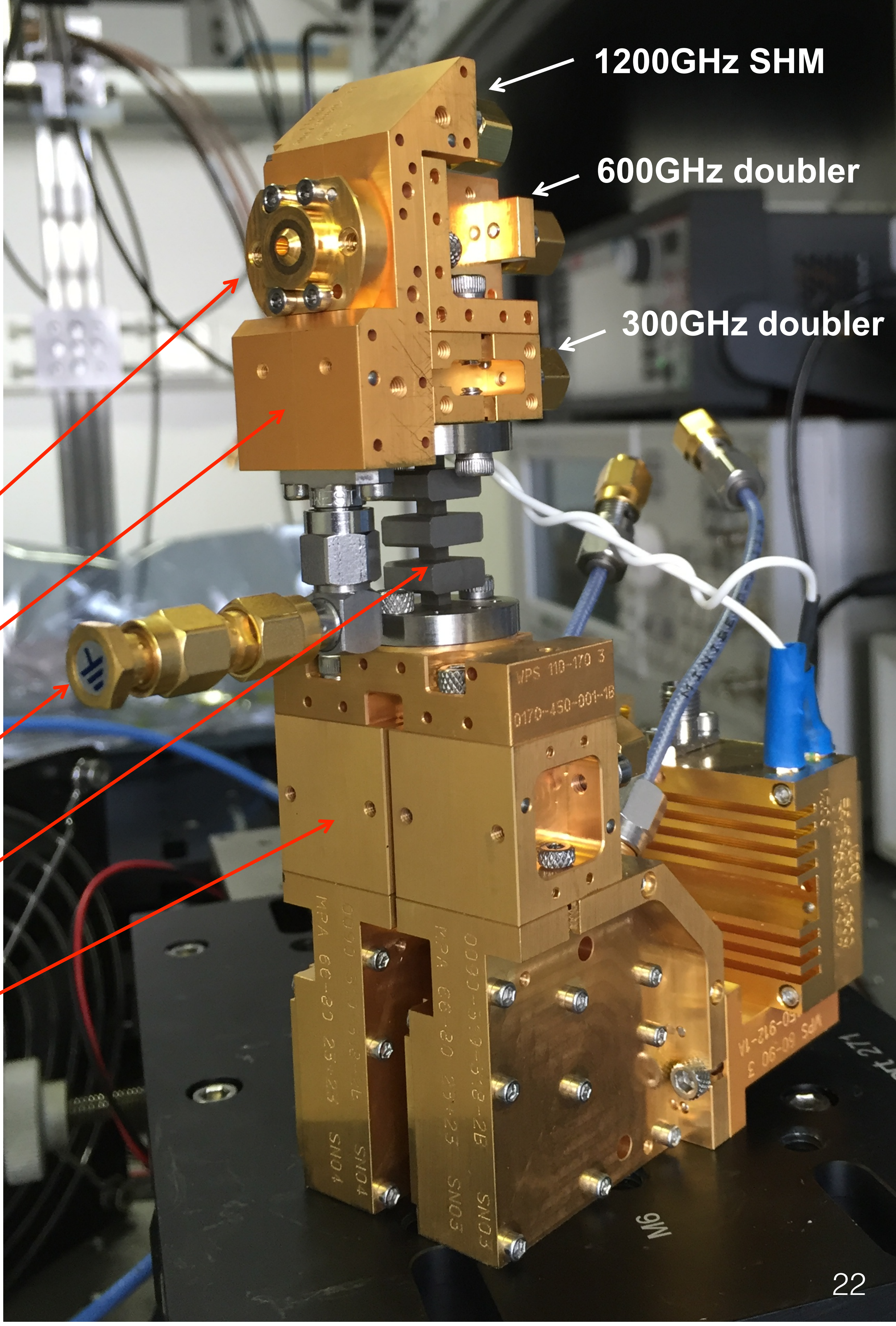
1200GHz feedhorn

1200GHz subharmonic mixer

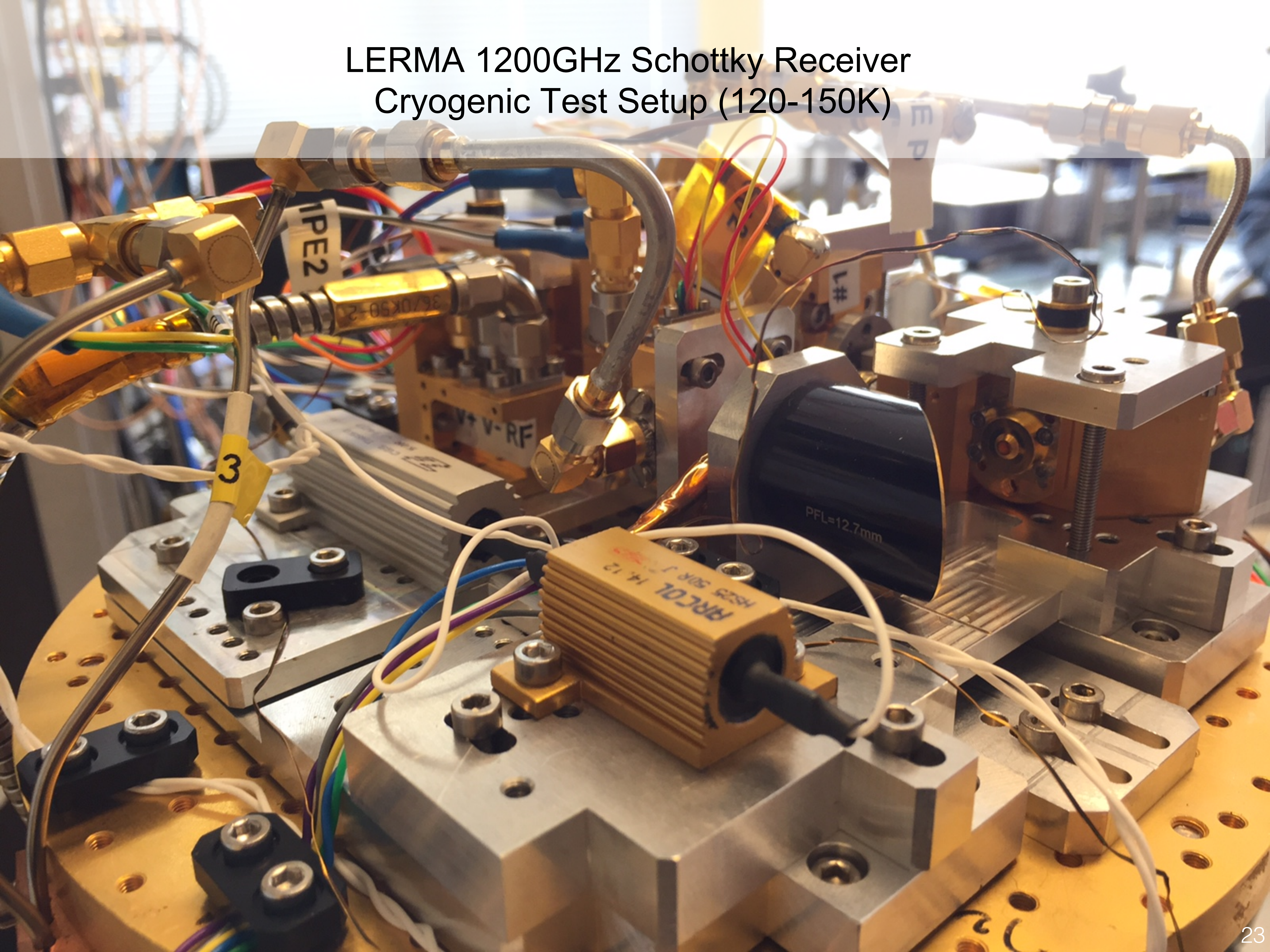
IF output

WR6.5 titanium thermal break

150GHz Local Oscillator chain



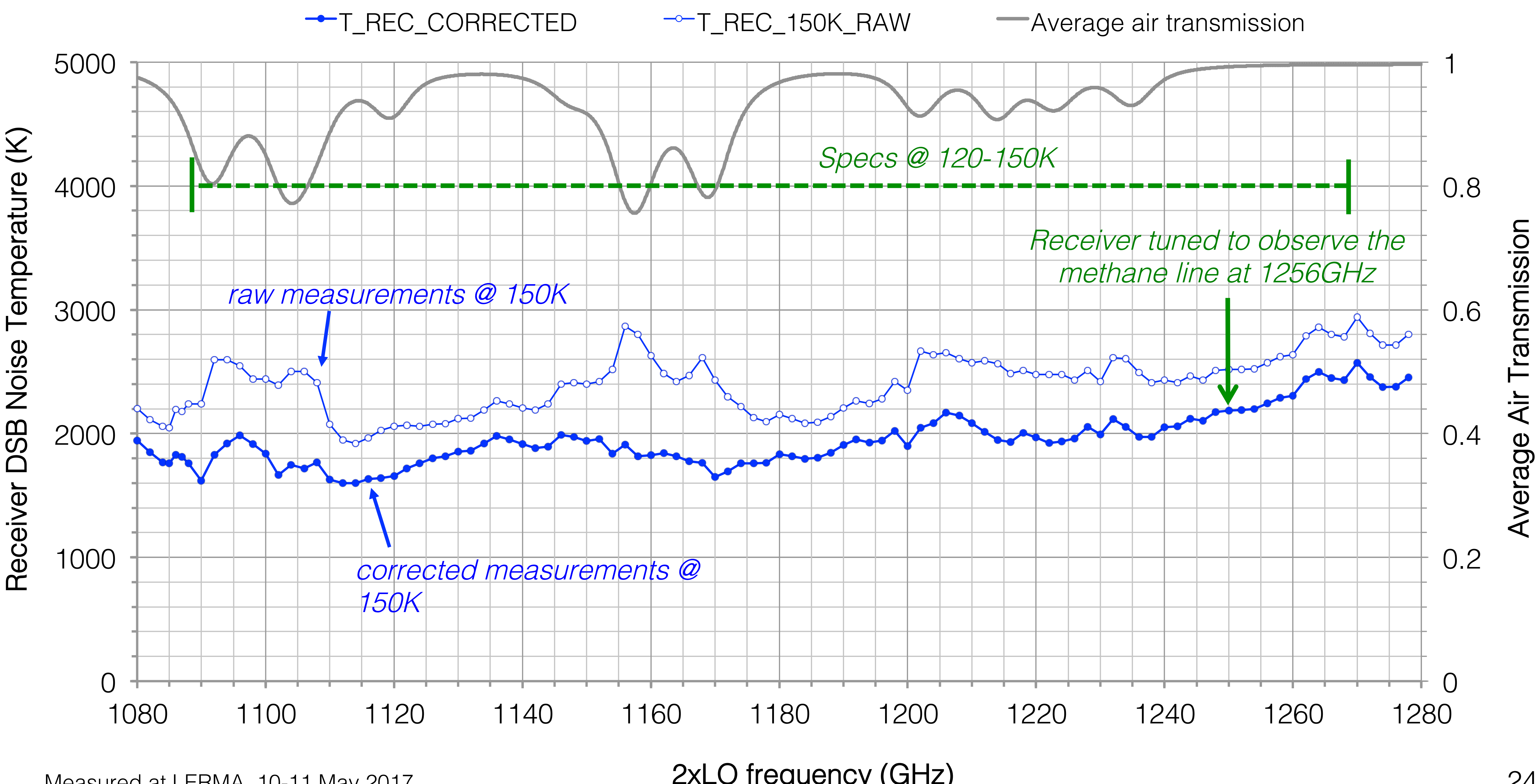
LERMA 1200GHz Schottky Receiver Cryogenic Test Setup (120-150K)



JUICE-SWI 1200GHz receiver sensitivity with baselined 150GHz LO chain and biased mixer

SHM1200-V1-RPG-SN01 with GaAs109-L6C4-A device

Data corrected for atmospheric absorption and cryostat window loss integrated for a 4.0-8.0GHz IF



Measured at LERMA, 10-11 May 2017

Current status of JUICE-SWI 1200GHz receiver frontend

- New 300GHz and 600GHz doubler flight devices fabricated with improved RF performance. Device qualification ongoing.

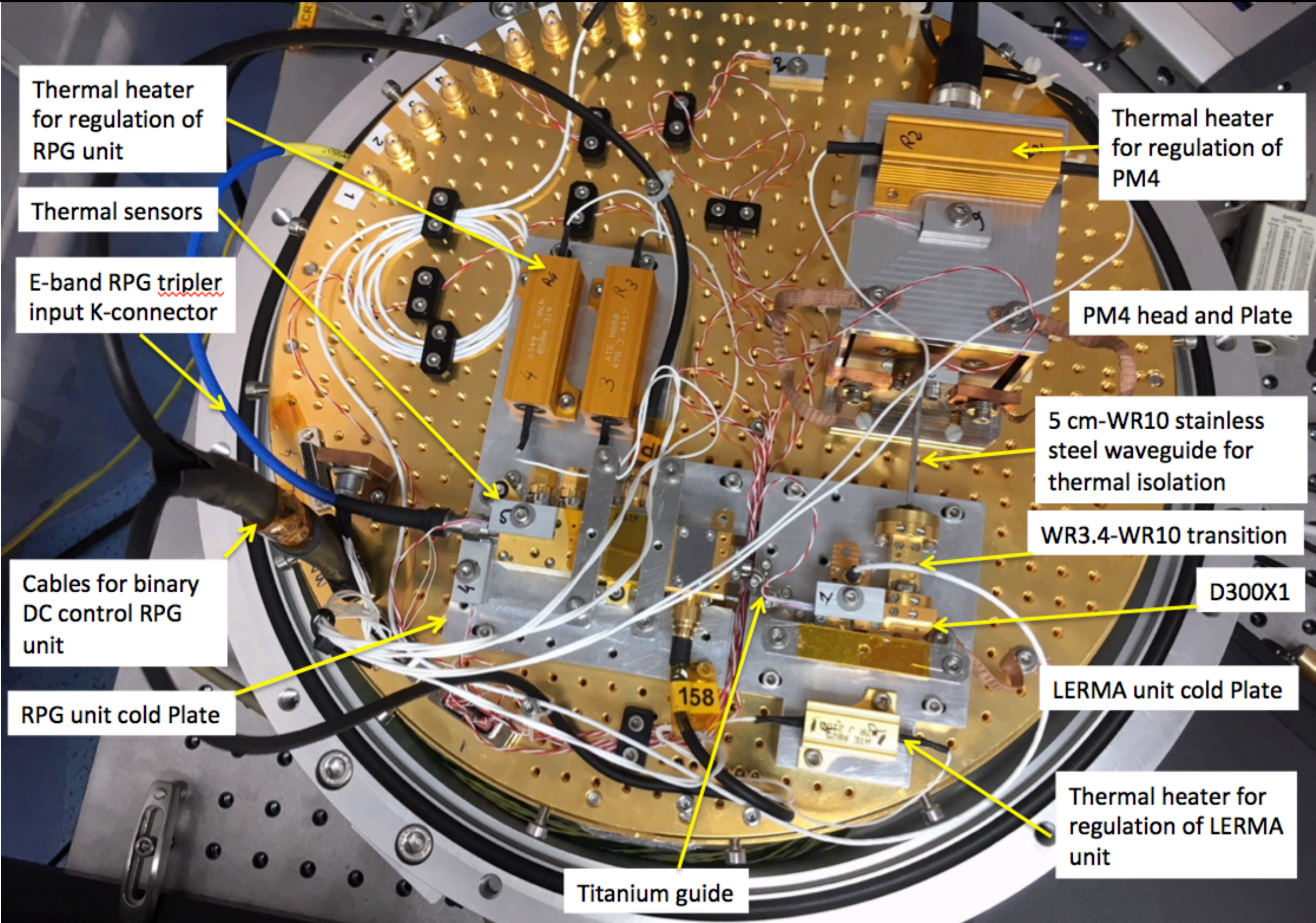
- 1200GHz flight mixer devices fabricated. Device qualification ongoing.

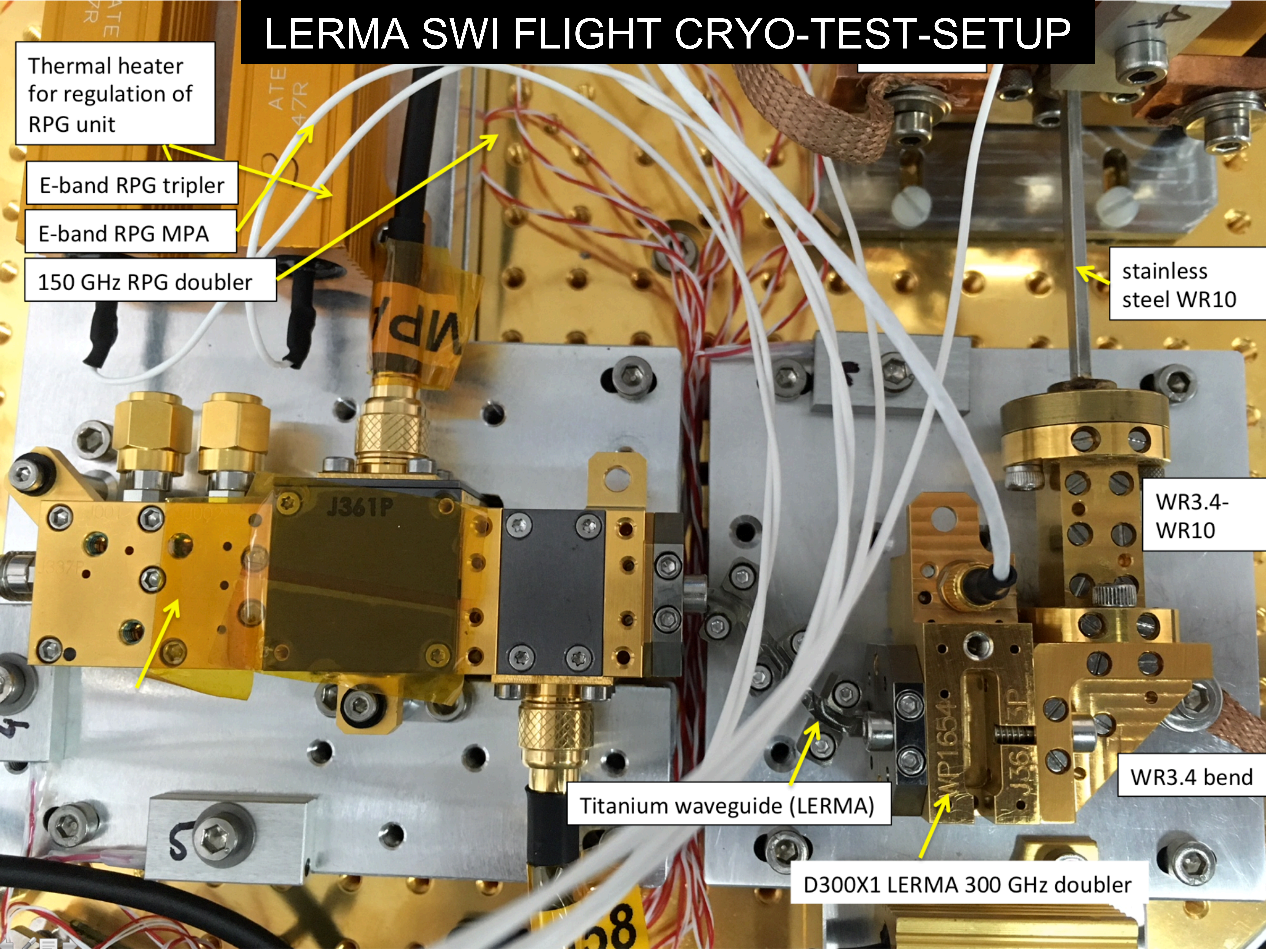
- EM micro-mechanical blocks fabricated at SAP-micro (FR), delivery of EM models ongoing

- STM model ready for shipment

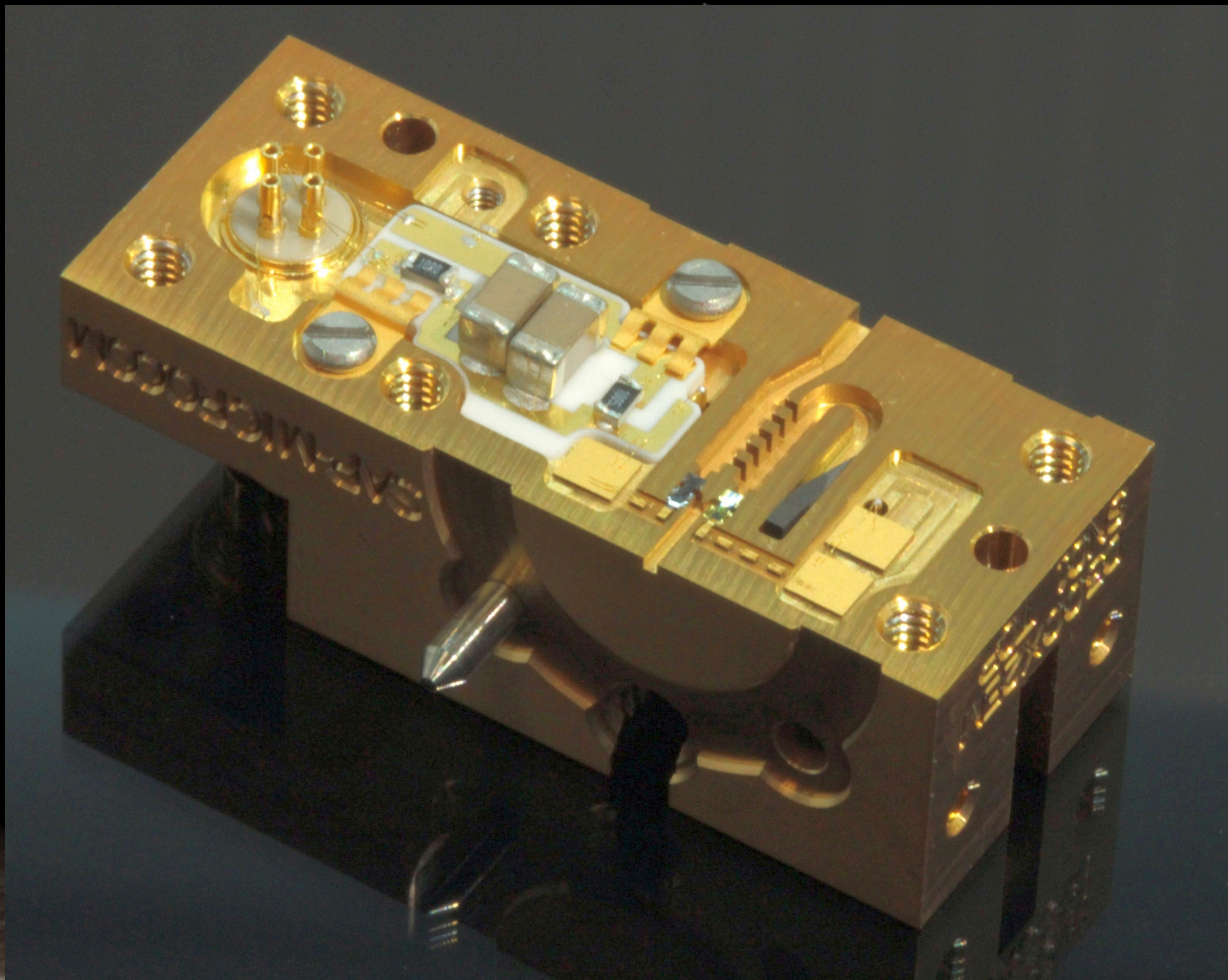
- New flight cryo-test setup and clean room in operation

LERMA SWI FLIGHT CRYO-TEST-SETUP

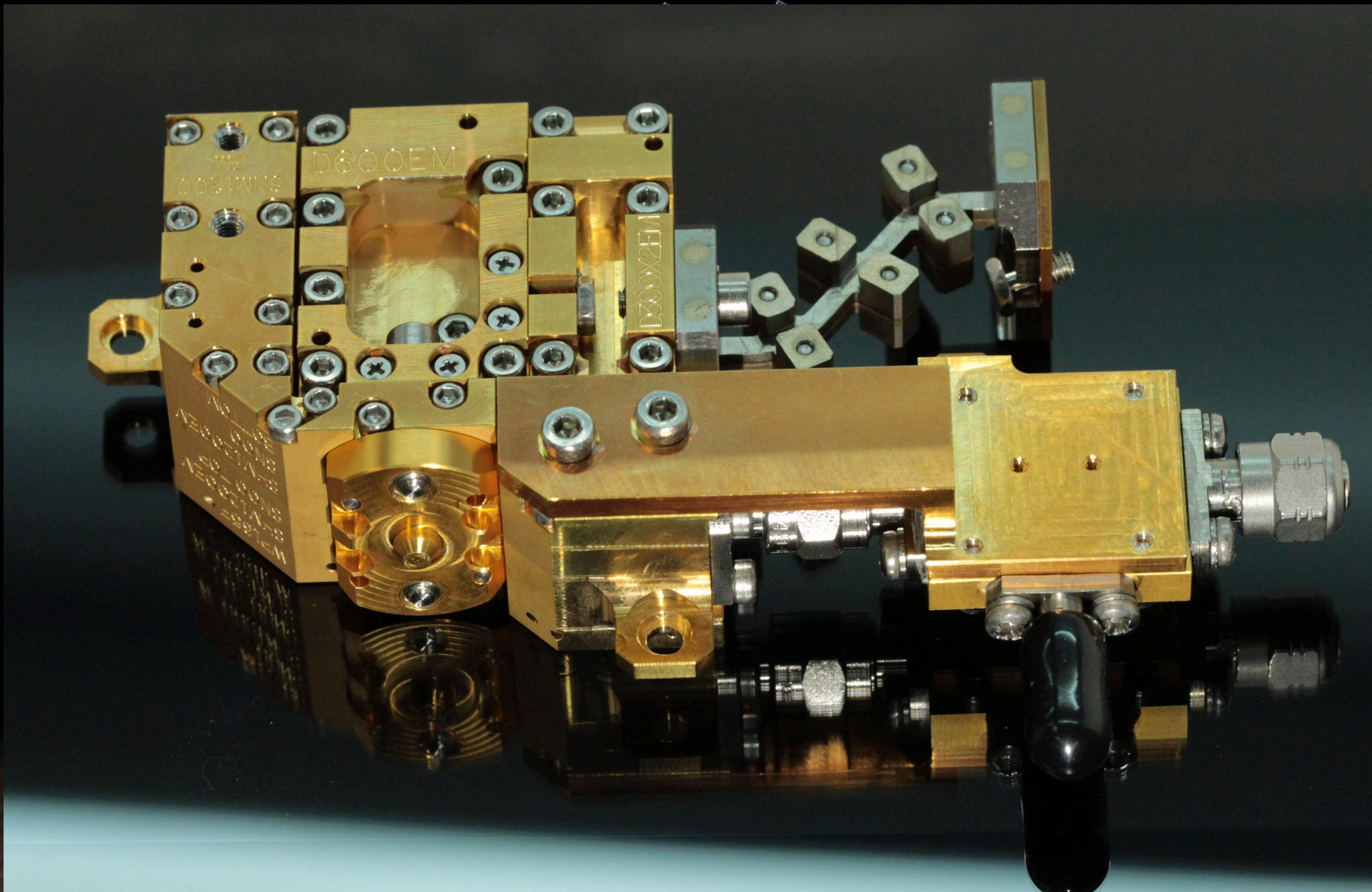



LERMA SWI FLIGHT CRYO-TEST-SETUP
Thermal heater for regulation of RPG unit
E-band RPG tripler
E-band RPG MPA
150 GHz RPG doubler
stainless steel WR10
WR3.4-WR10
J361P
WR3.4 bend
Titanium waveguide (LERMA)
D300X1 LERMA 300 GHz doubler

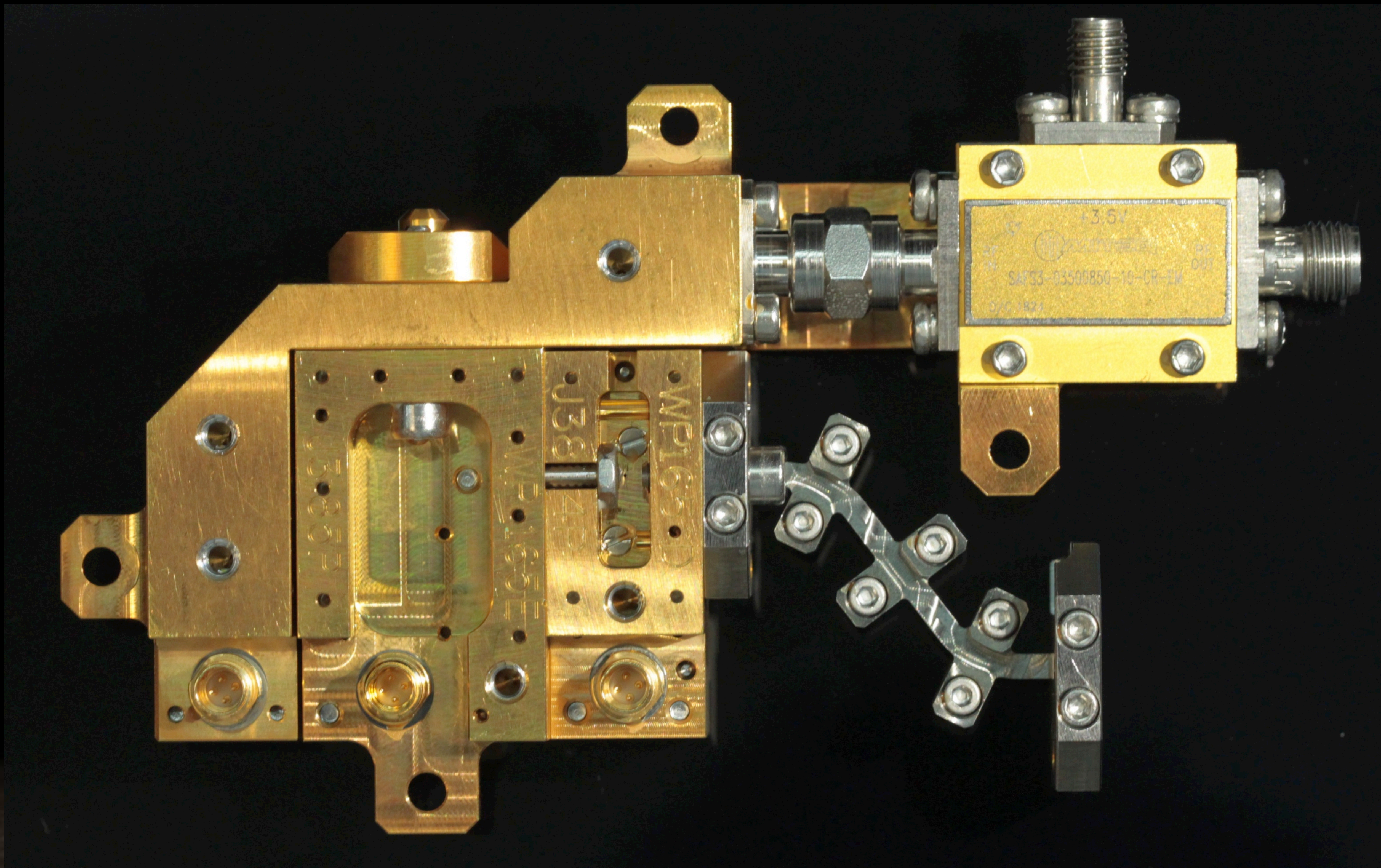
SWI D300X2-EM 300GHz Dual-Chip Doubler



SWI 1200GHz Receiver Front-End STM



SWI 1200GHz Receiver Front-End STM



END

Thanks for your attention!
Do you have questions ?