Millimeter and sub-millimeter technology developments in France
(for observations of the atmosphere)

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R&D for Front-end components

- ✓ Schottky mixers (Observatoire de Paris, IRAM)

  => give the best sensitivity for uncooled receivers at frequency above 150-180GHz. Very stable mixers can be built (good for radiometers)

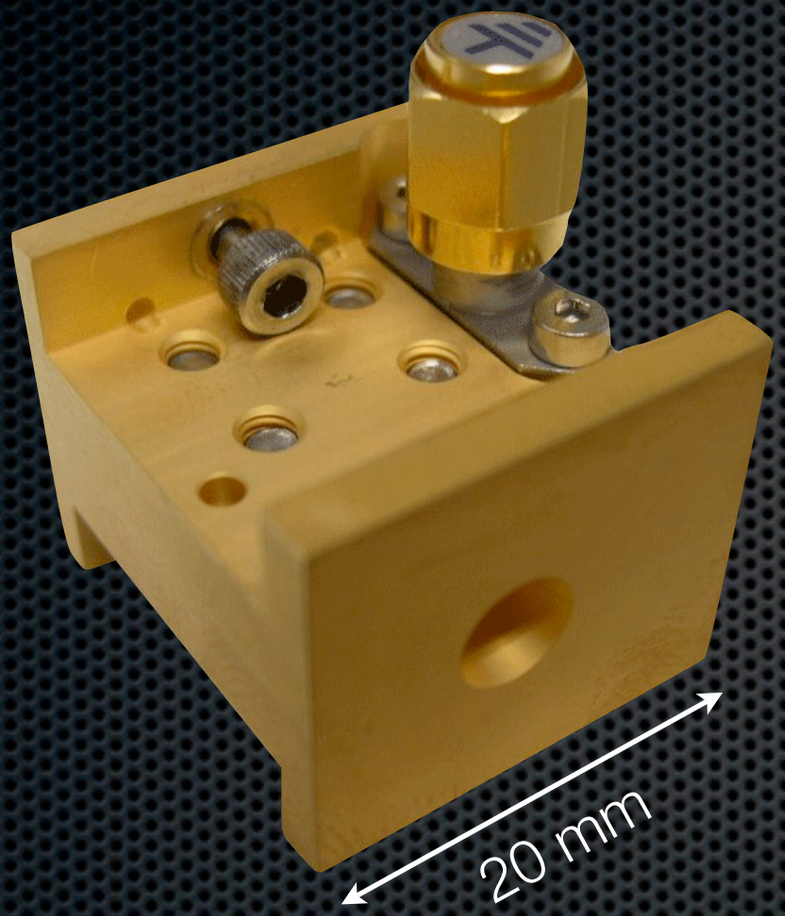
- ✓ Frequency multipliers (Observatoire de Paris, IRAM)

  => are necessary to generate the Local Oscillator signal (Gunn diode technology is now obsolete). Schottky diodes are the most efficient devices to date.

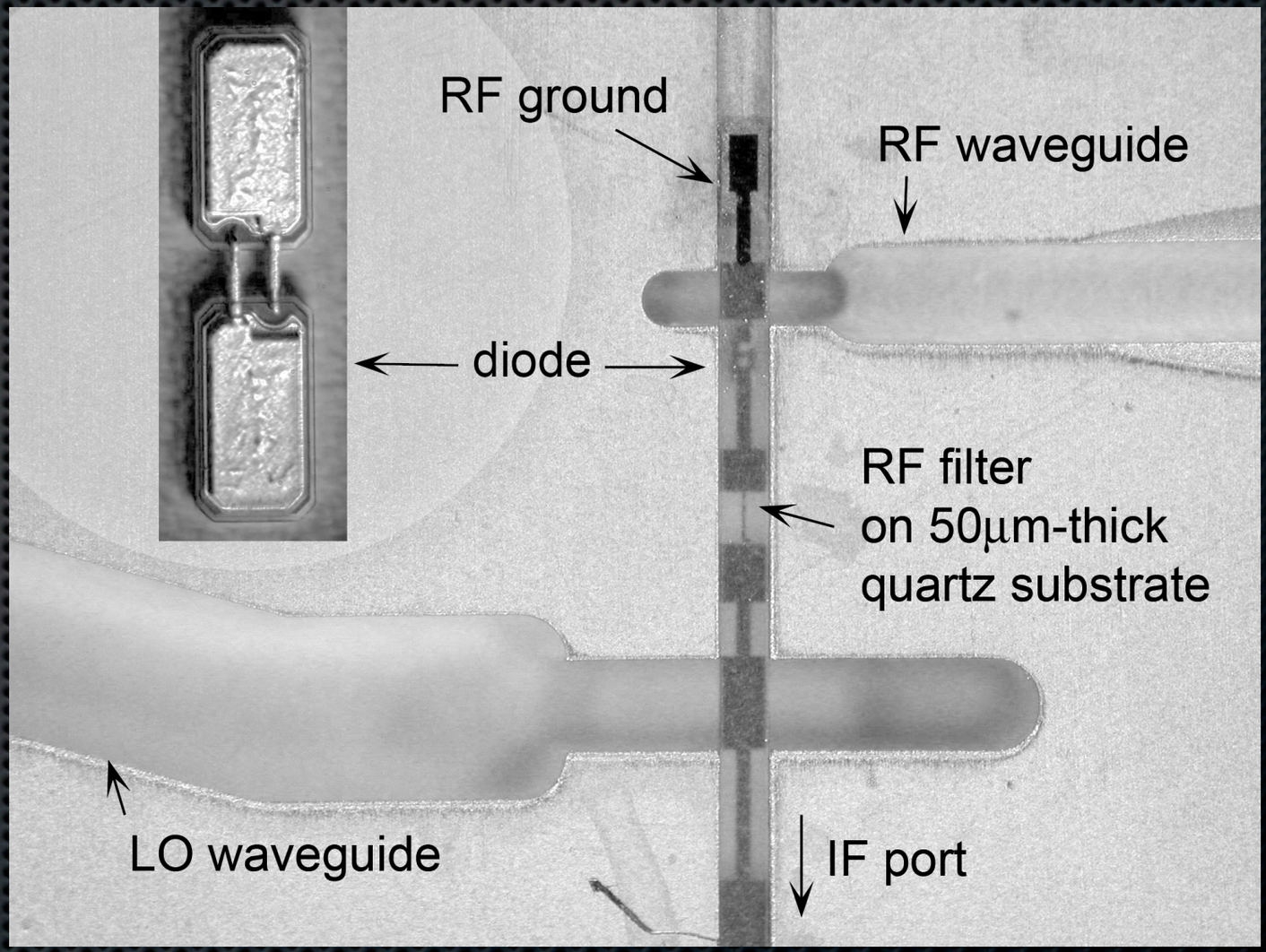
- ✓ Low-Noise-Amplifiers at frequencies above 100GHz (ASTRIUM)

  => to create single channel receivers instead of dual channel receivers (mixers). Give better receiver sensitivity than mixers at frequencies bellow 150-180GHz. Highly integrated receivers can be built. Expensive technology.

Example of a Sub-millimeter Mixer



300-360GHz SH mixer with Schottky diodes from Virginia (USA)



Design B. Thomas, Observatoire de Paris, LERMA

R&D for Front-end components

- ✓ Frequency Selective Surface (ASTRIUM)

  => to separate frequency bands and create multi frequency receivers.

- ✓ Calibration targets at frequency above 100GHz (LMD)

  => very important for calibration accuracy. Can be heavy and cumbersome.

R&D for Device technology

- ✓ Schottky diode development

  => Laboratoire de Photonique et de Nanotructure (CNRS)

  => United Monolithic Semiconductors BES process (France / Germany)

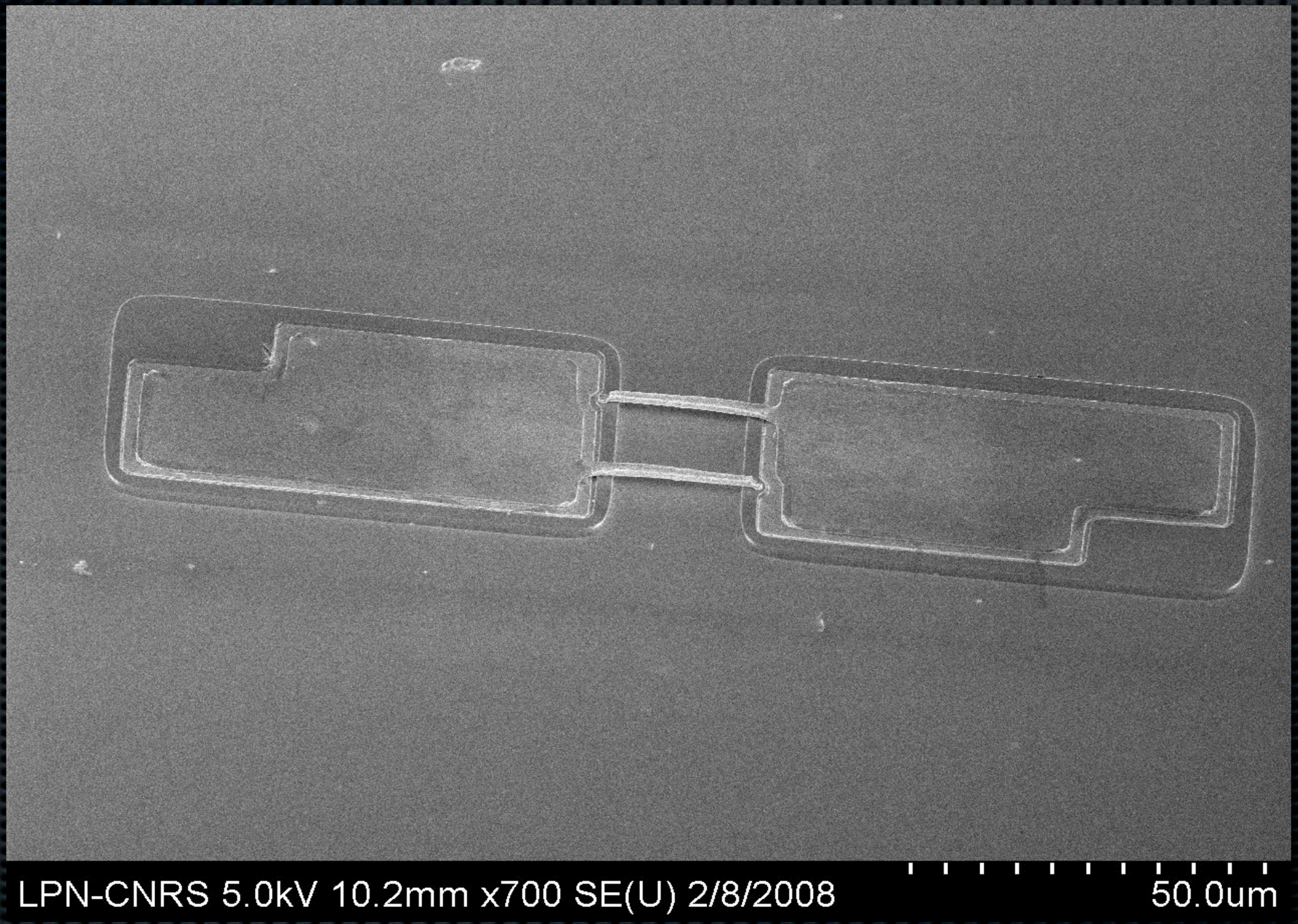
  A clean room for Schottky diode fabrication can be set-up for a few M€

- ✓ High Electron Mobility Transistors

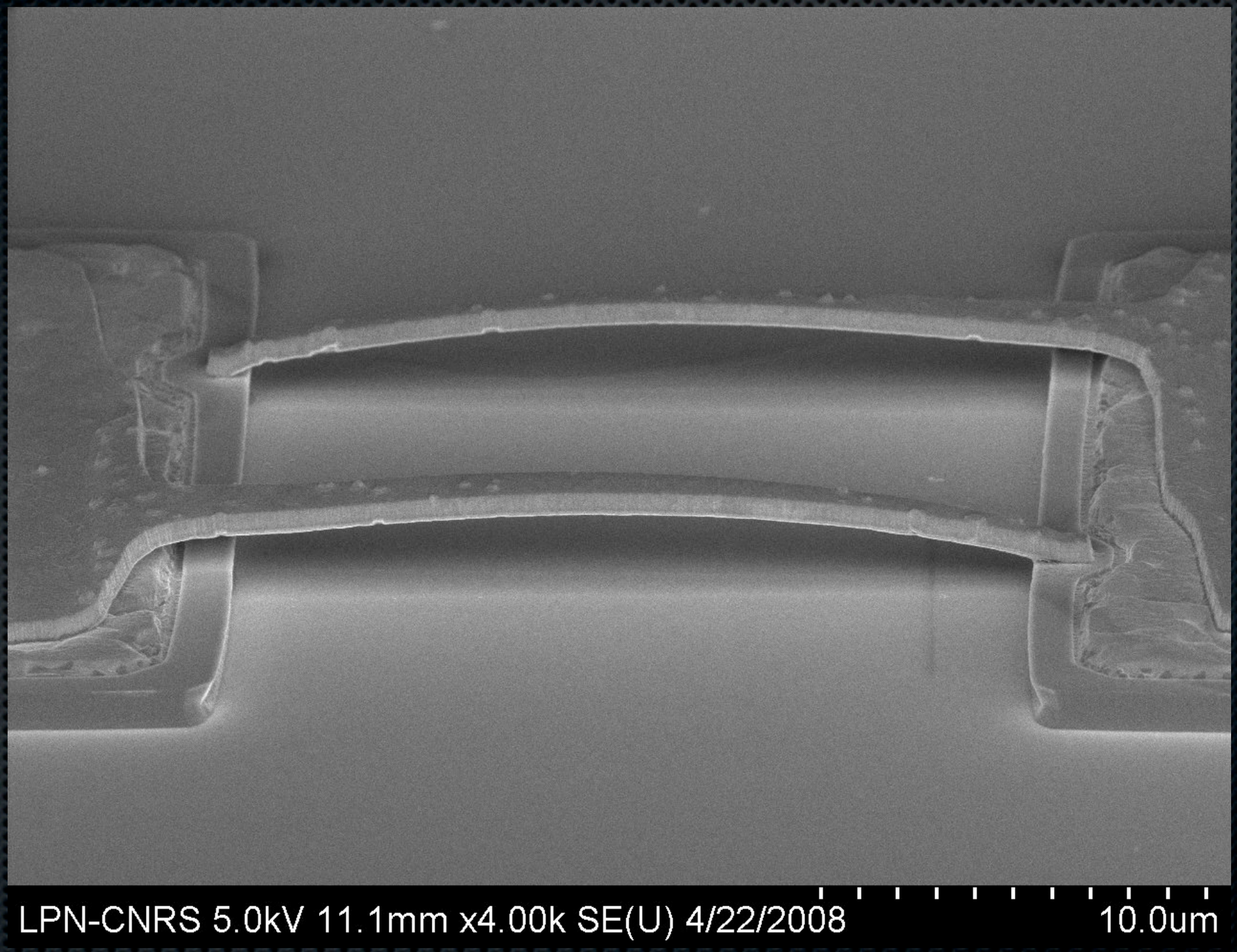
  => IEMN (CNRS / University of Lille)

  => UMS, OMMIC (Industrial suppliers)

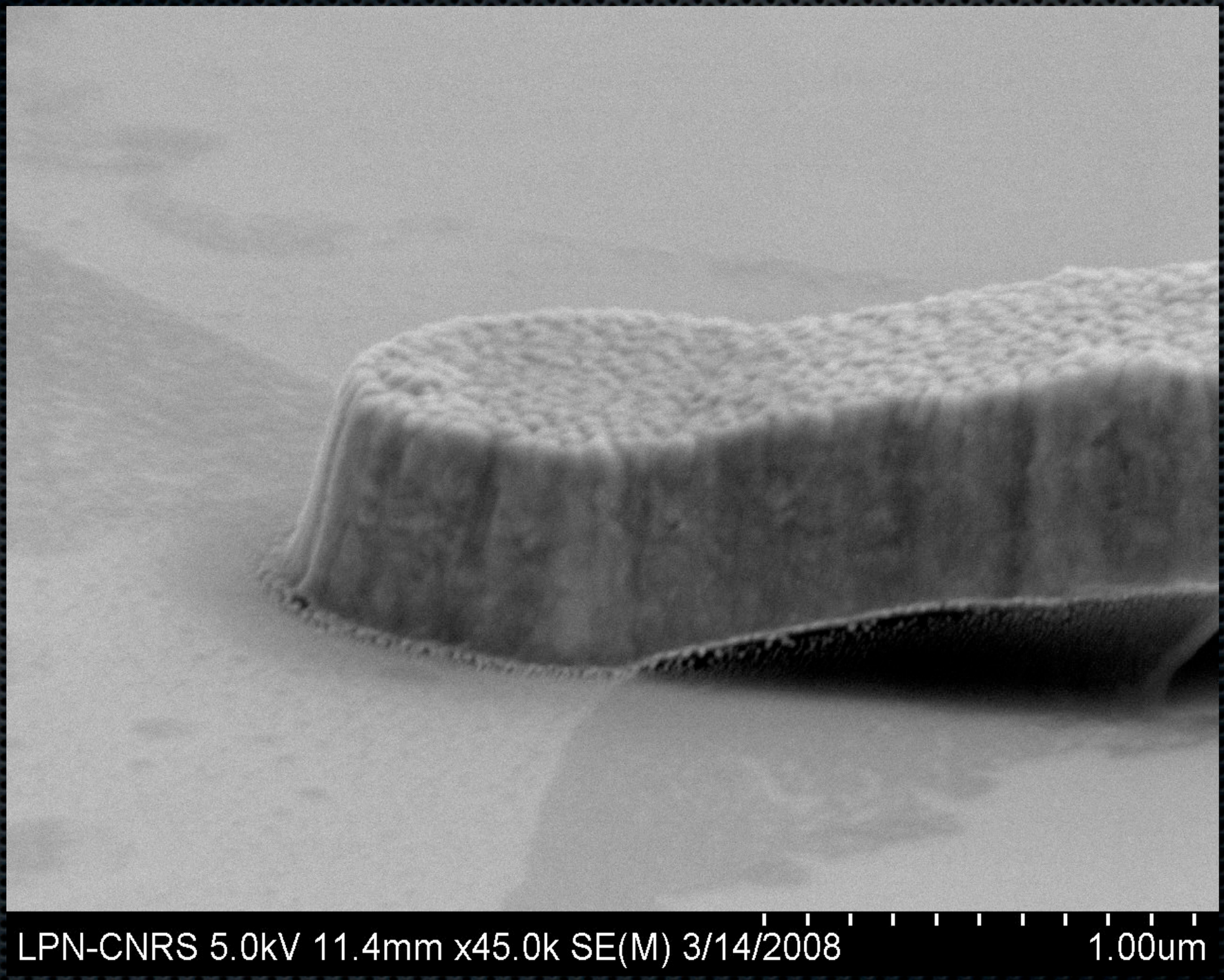
LPN Schottky Diodes



LPN Schottky Diodes

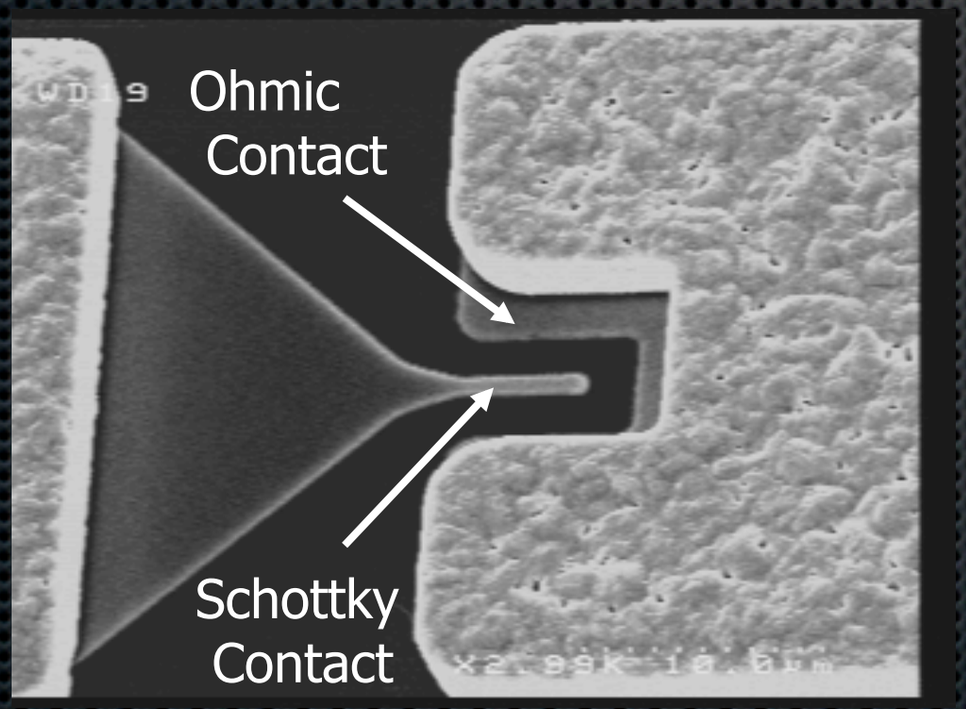


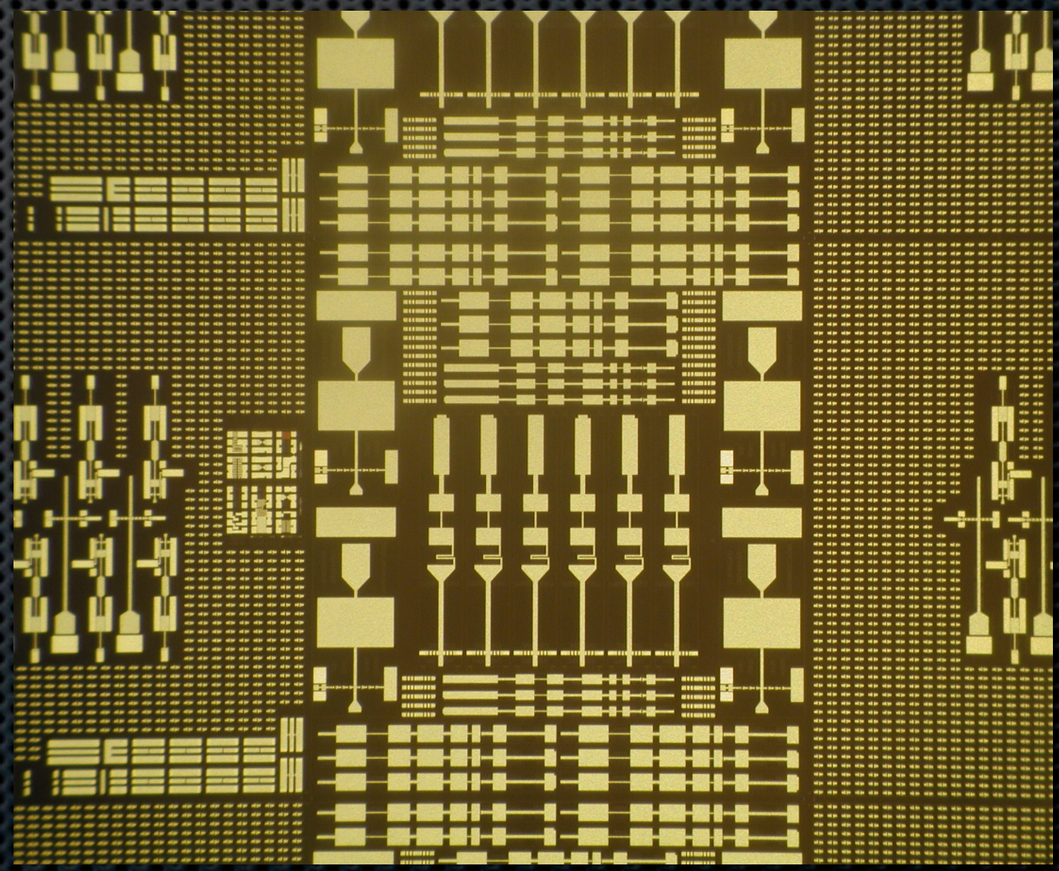
LPN Schottky Diodes



UMS Schottky Diodes

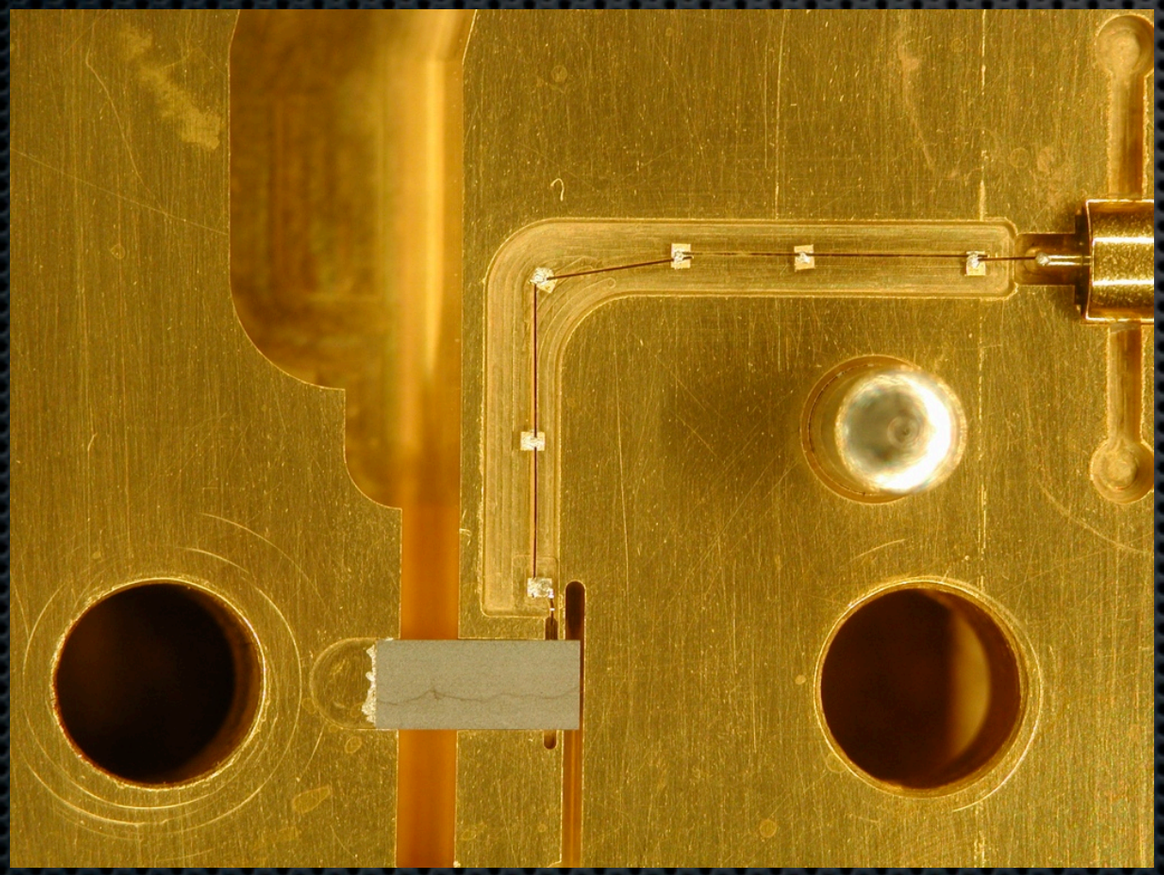
- CNES and ESA seek independence from the USA for millimeter-wave and submillimeter wave Schottky diodes. UMS was chosen as a possible industrial provider.

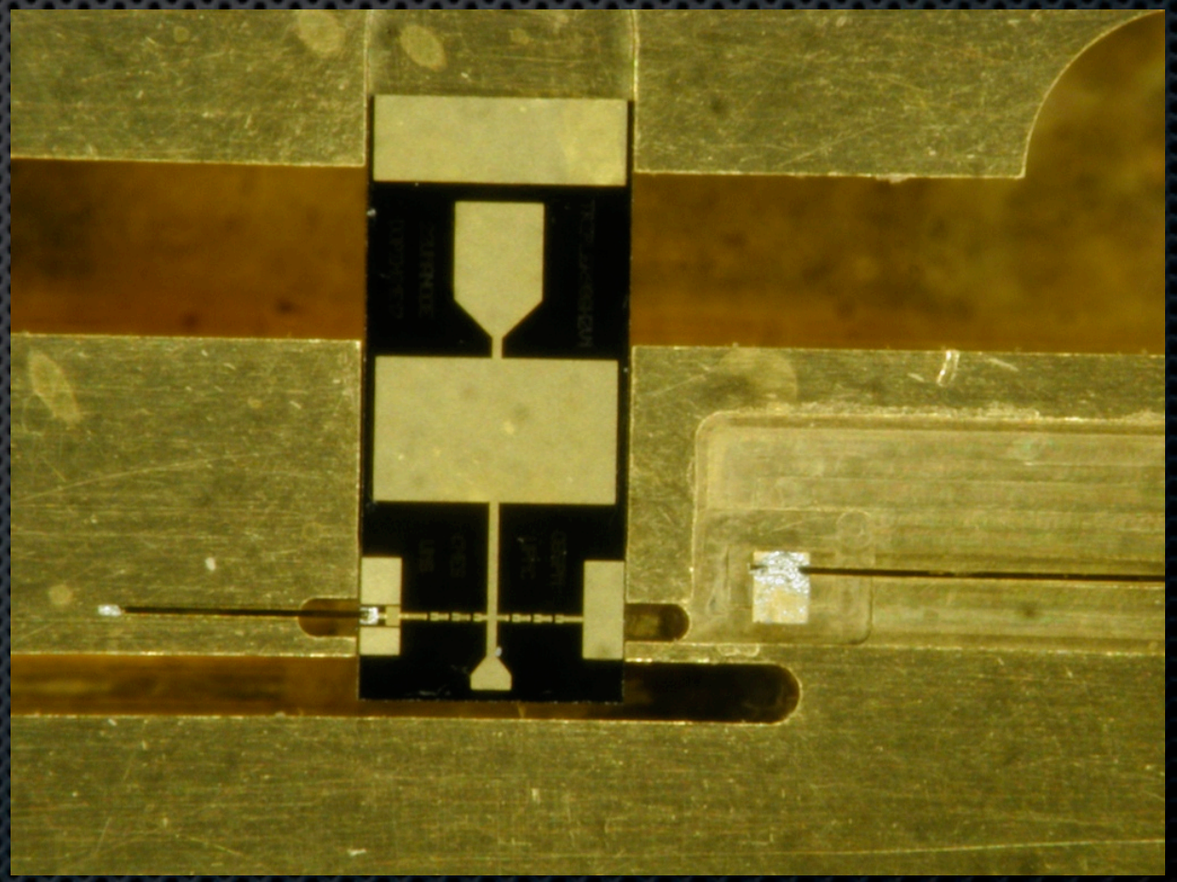




90 GHz Balanced Tripler with UMS Diodes

- 5% efficiency and 4mW at 90GHz





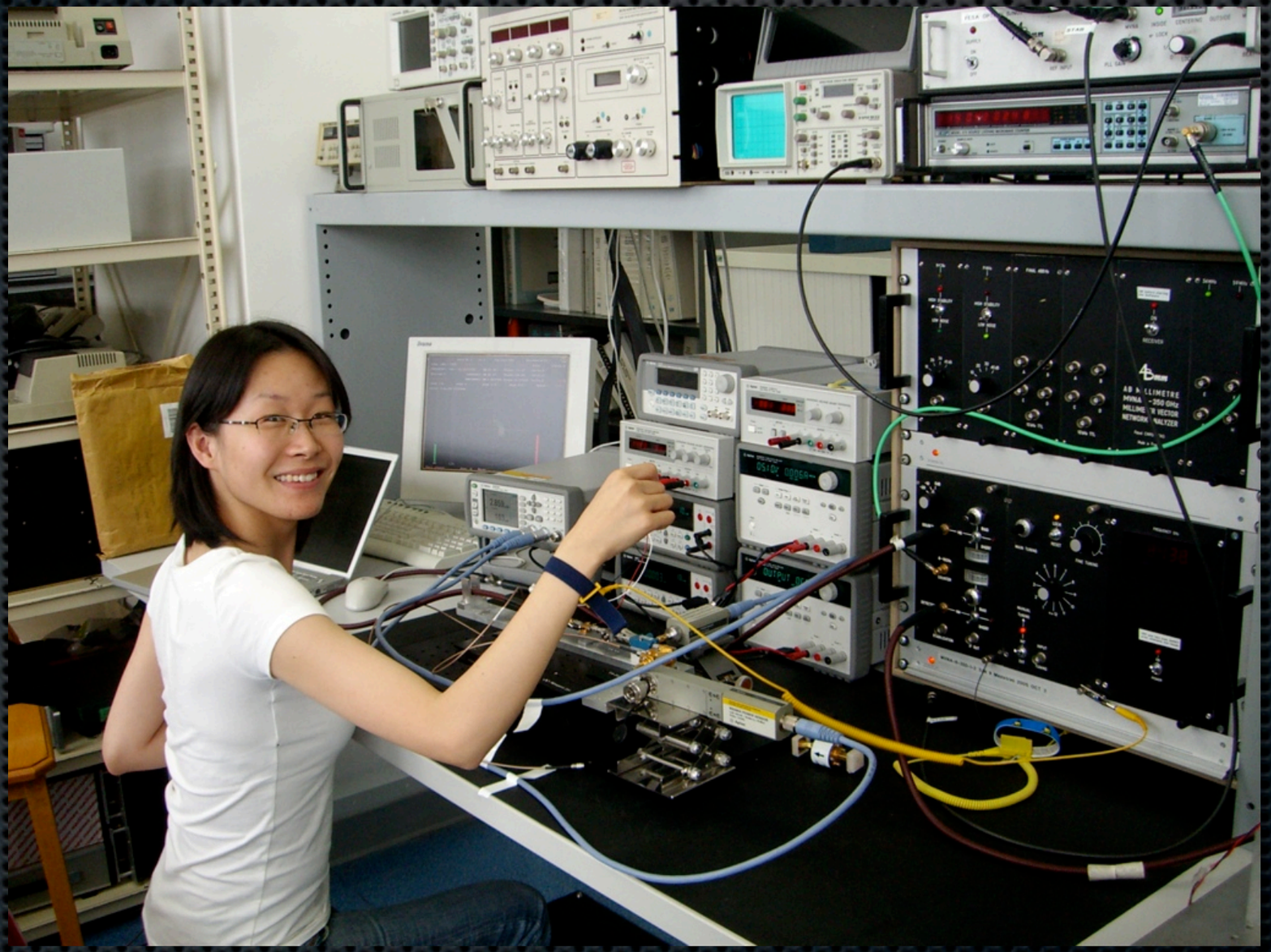
Design Hui Wang, Observatoire de Paris, LERMA

LPN Schottky Diodes

- LPN has a 1000 m2 clean-room, specialized in III-V material (GaAs, InP) and with high quality MBE epitaxy and MOCVD epitaxy capabilities
- Diode topology similar to Jet Propulsion Laboratory diodes but fabricated with a full e-beam process
- Good DC characteristics
- First RF results expected this autumn

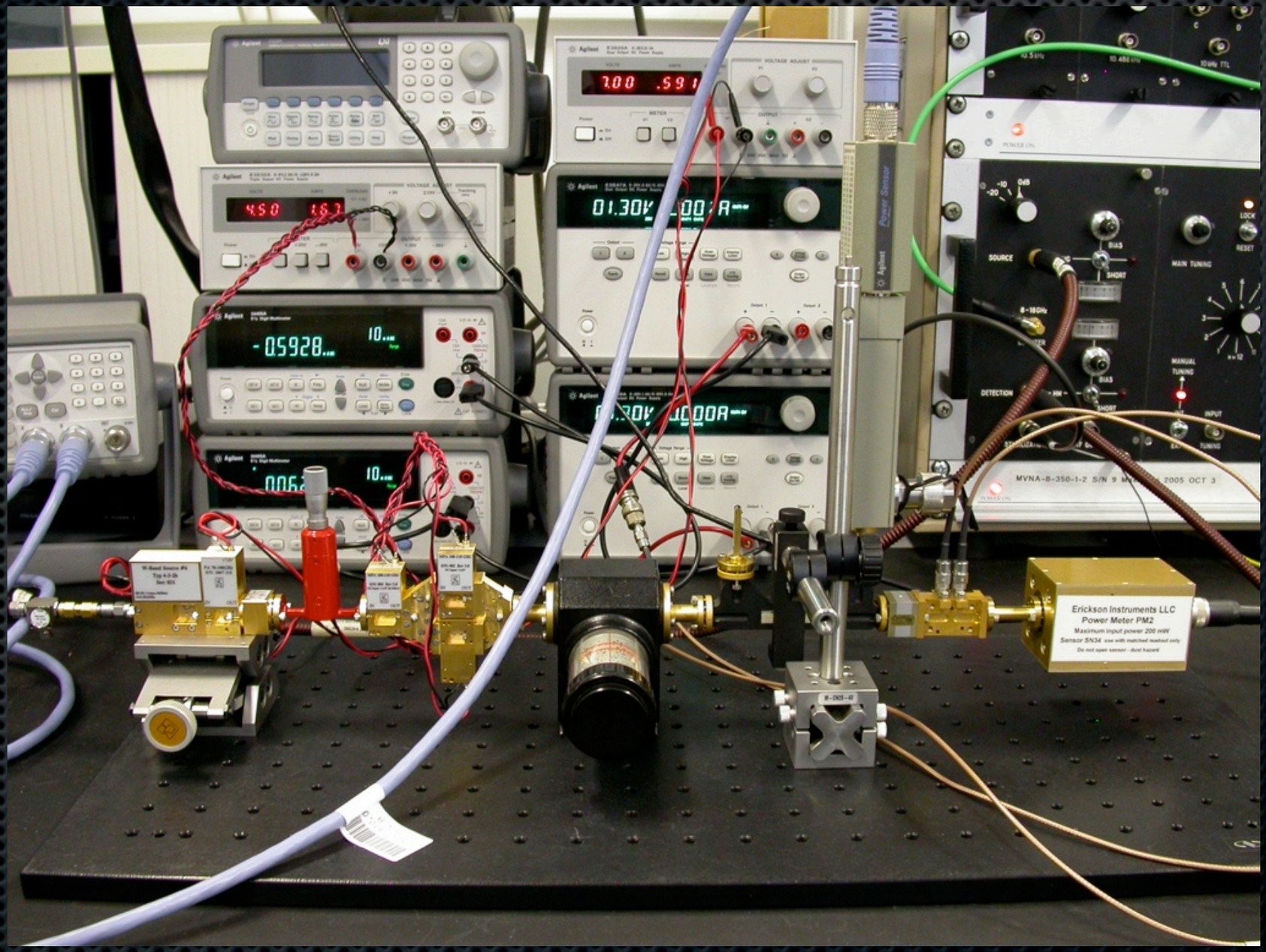
Sub-millimeter test setup

- Frequency multiplier test setup



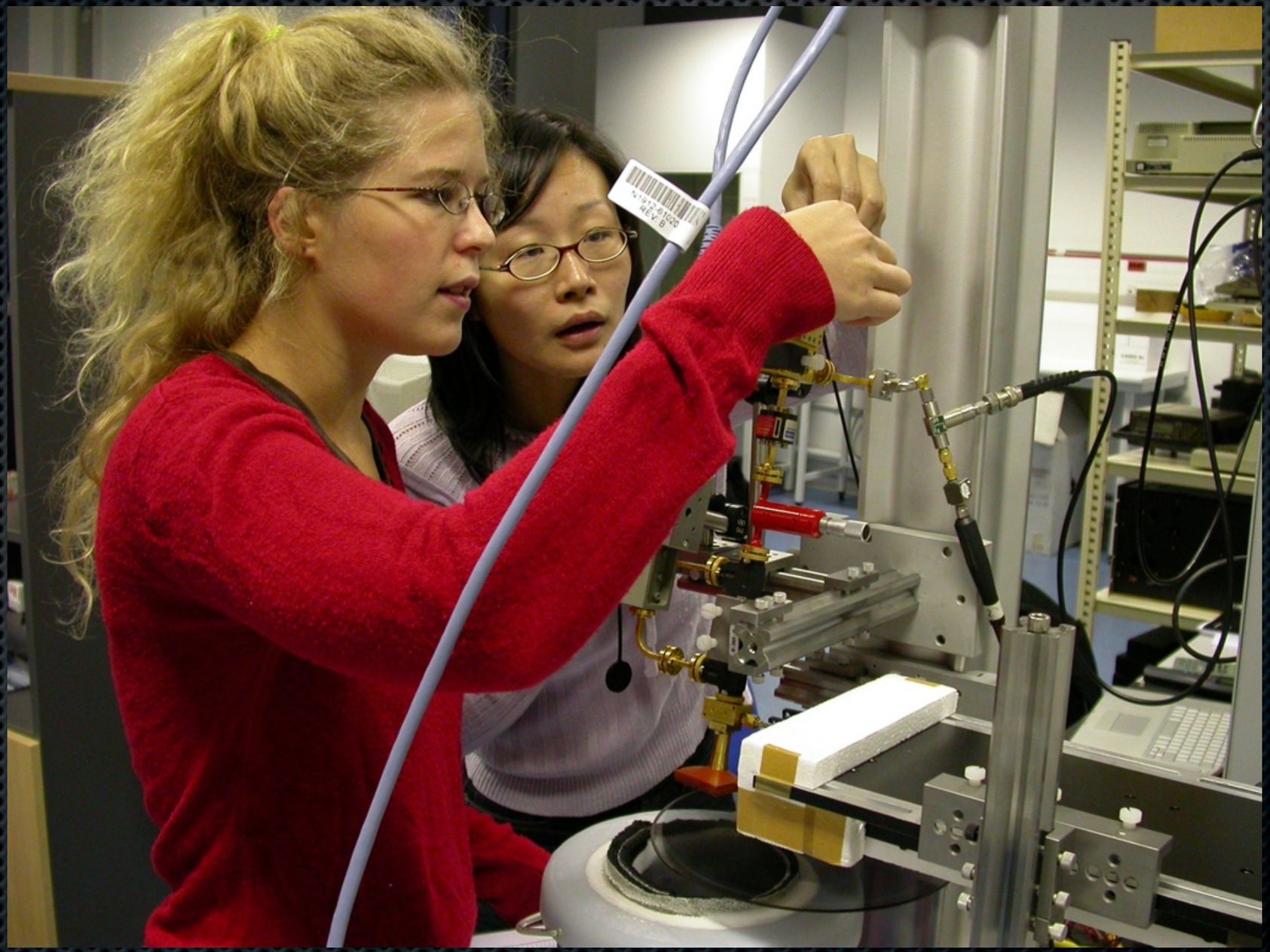
Sub-millimeter test setup

- Frequency multiplier test setup



Sub-millimeter test setup

- Mixer test setup



Collaboration with JPL / RAL

- 875GHz Sub-Harmonic Mixer
  - ☑ Designed at Observatoire de Paris / Rutherford Appleton Laboratory
  - ☑ Mechanical block machined at RAL
  - ☑ Membrane chip fabricated at JPL
  - ☑ Assembly and tests performed at JPL

- State-of-the-art results
  - ☑ Best mixer noise temperature (2600K DSB at 848GHz)
  - ☑ Best conversion losses (10dB DSB)
  - ☑ Only 3mW of LO power