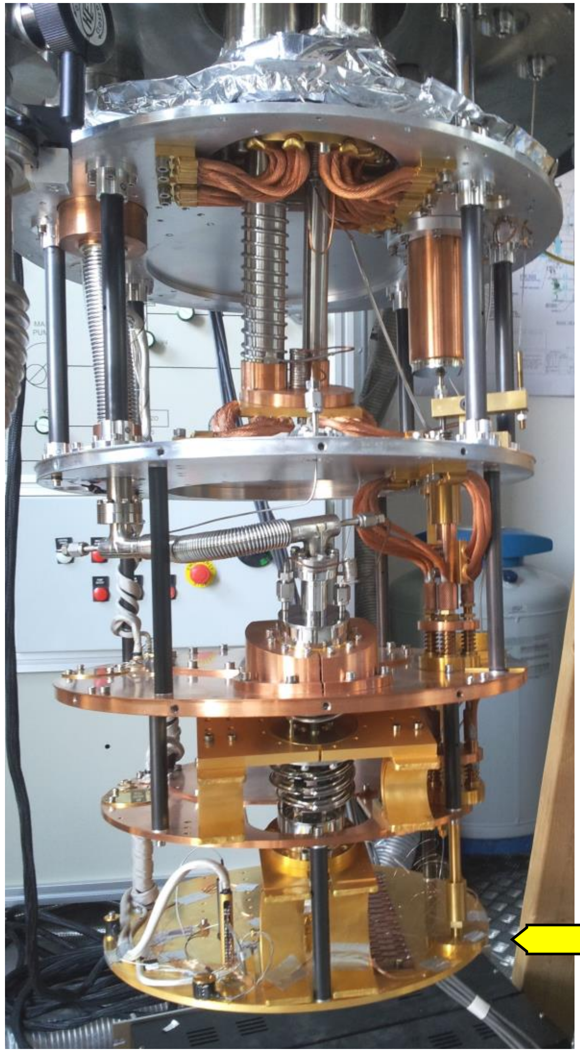
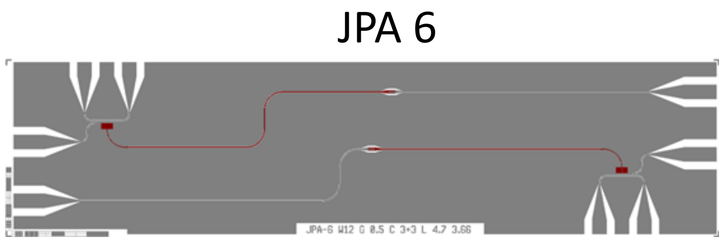
Measurements on JPA 6 - novembre 2022
(Andrea Vinante, Trento)

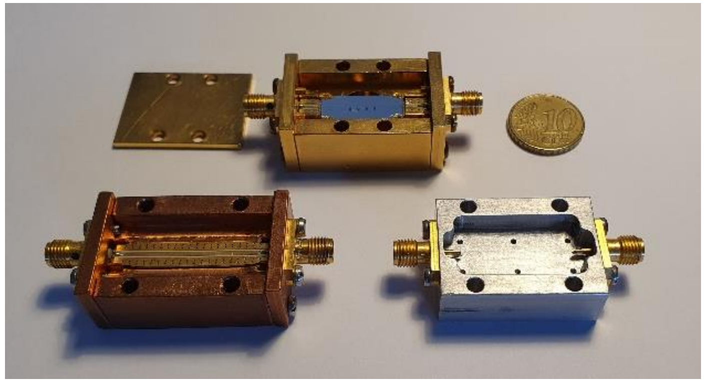
- Experimental scheme
- What we wanted to see
- What we have seen

???
??? discussion ???
???

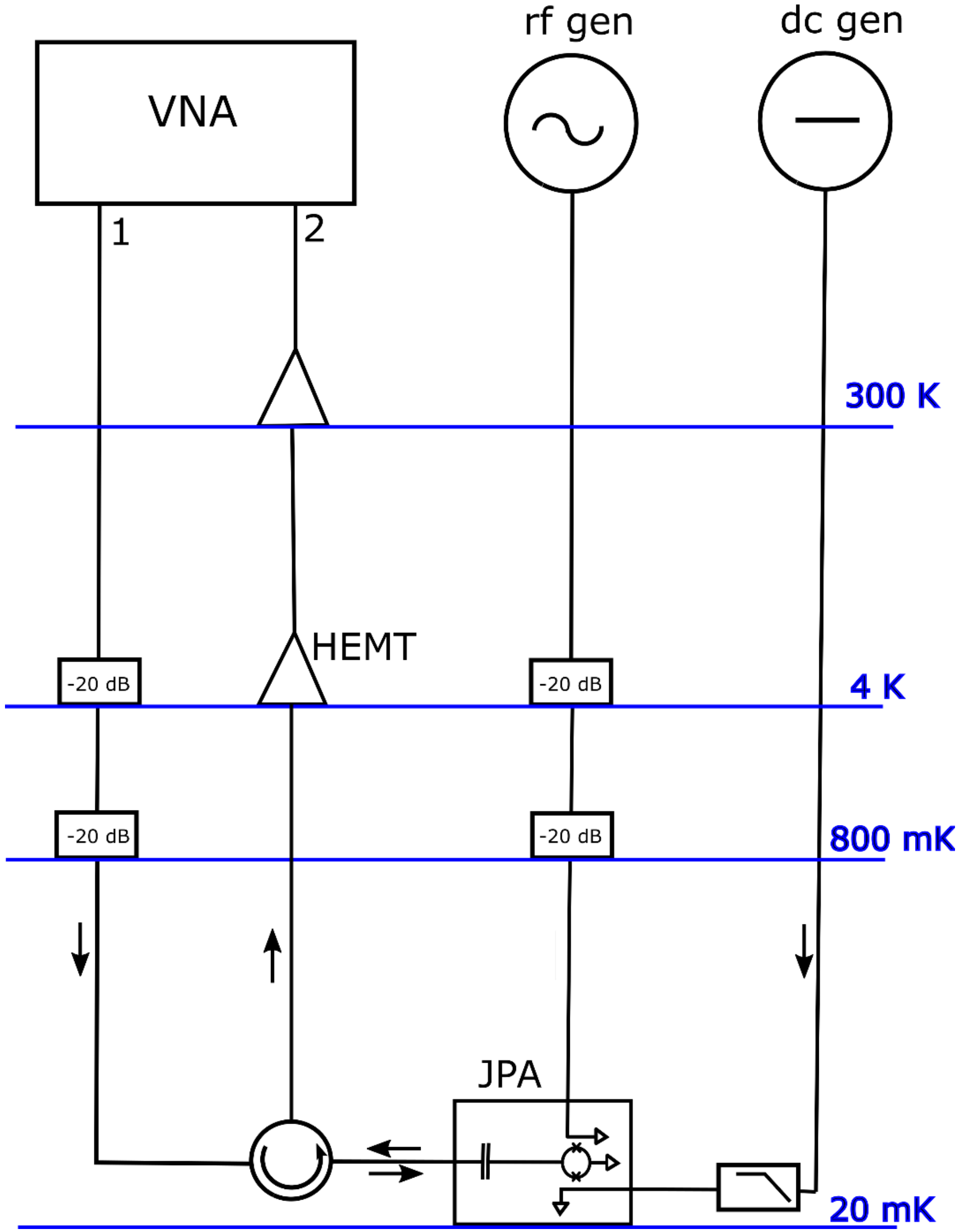
Experimental setup



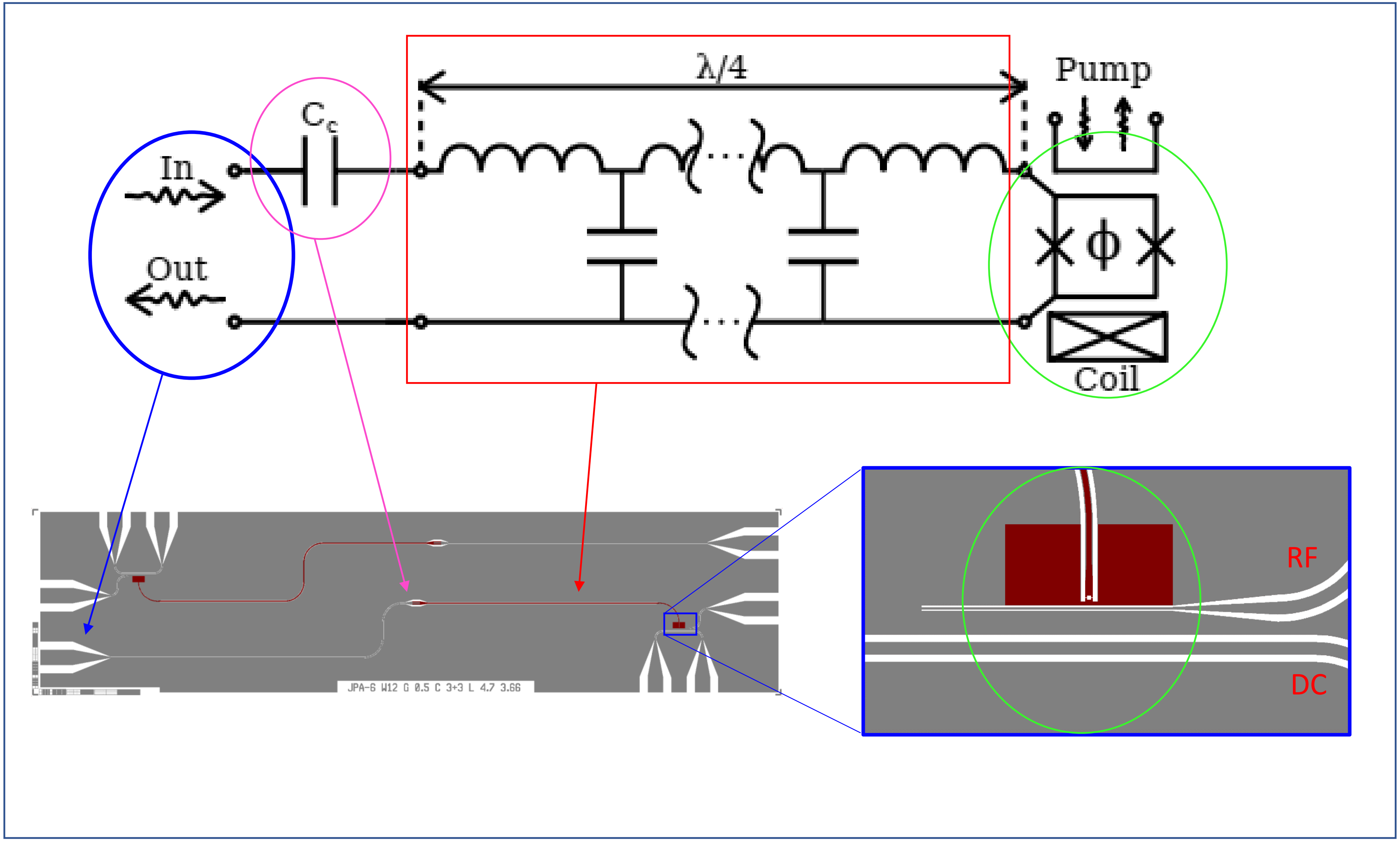




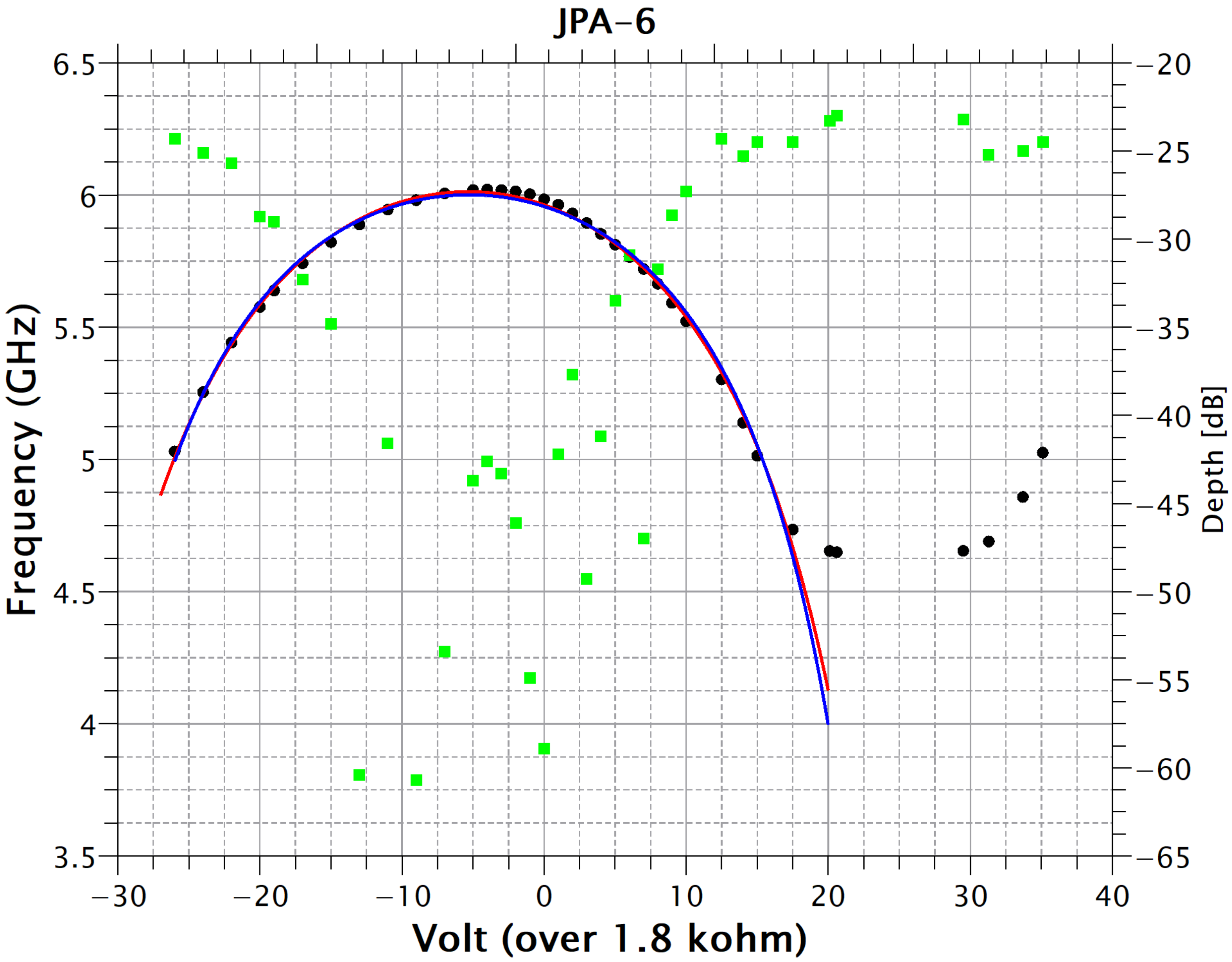
Janis Dilution refrigerator $T_0 \approx 30$ mK



JPA 6



Tuning curve from VNA



Coupling = 34 mA/Φ_0

$$f = \frac{f_0}{1 + A\,cos(\pi\Phi/\Phi_0)}$$

$$f_0 = 7.5\ GHz$$

$$A = 0.25$$

$$f = \frac{f_0}{\sqrt{1 + A\,cos(\pi\Phi/\Phi_0)}}$$

$$f_0 = 8.0\ GHz$$

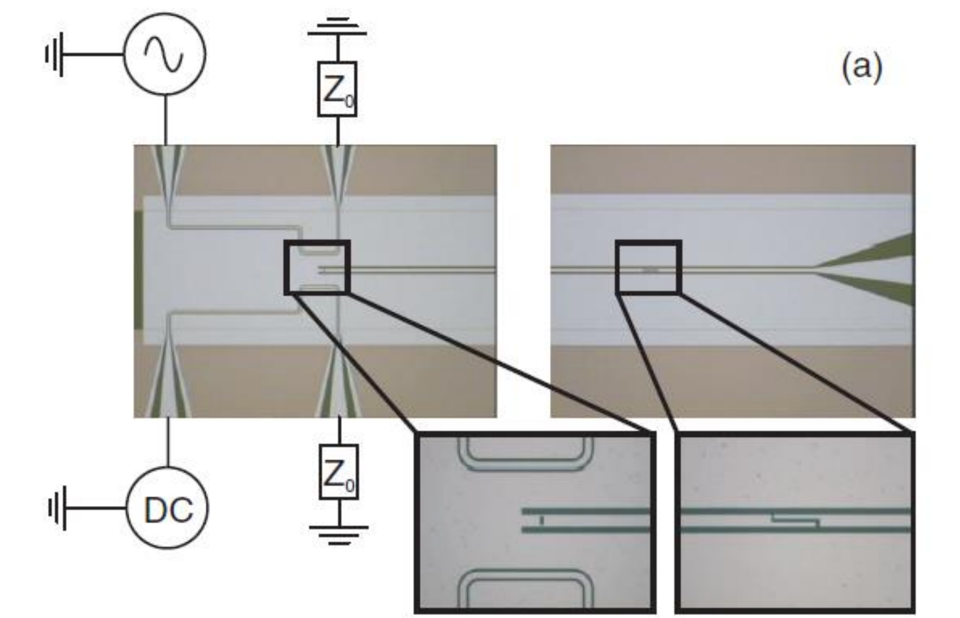
$$A = 0.8$$

What we expect to see (1) : parametric bifurcation/instability

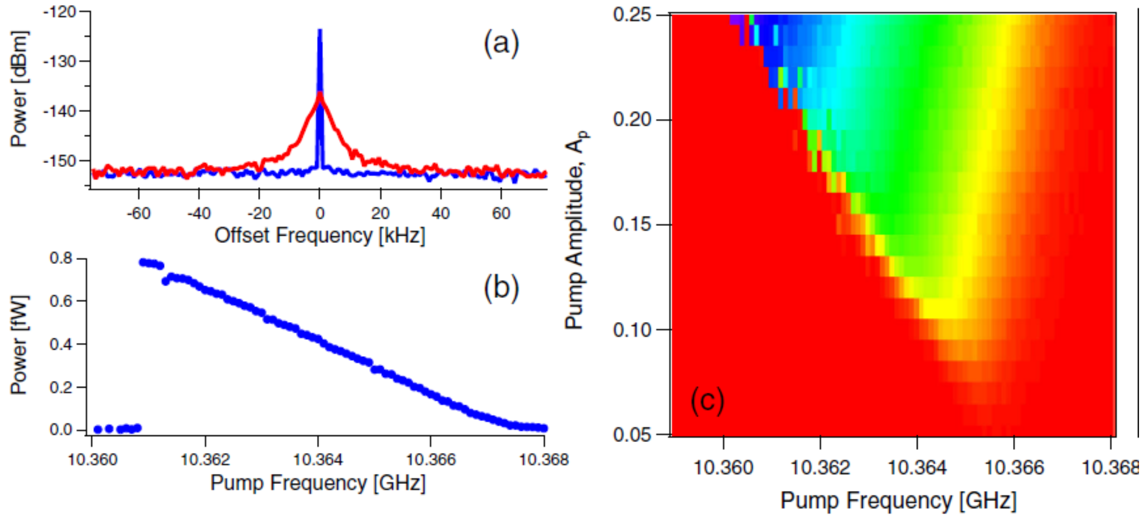
Photon Generation in an Electromagnetic Cavity with a Time-Dependent Boundary

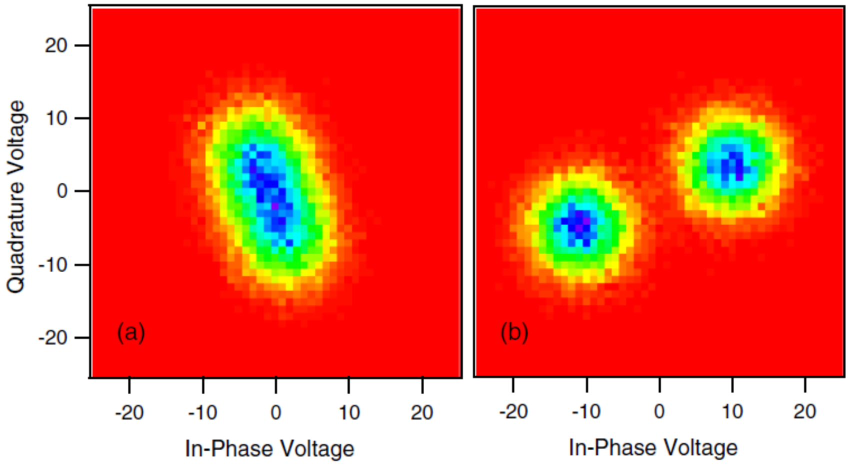
C. M. Wilson,[1] T. Duty,[2] M. Sandberg,[1] F. Persson,[1] V. Shumeiko,[1] and P. Delsing[1]

PRL **105,** 233907 (2010) PHYSICAL RE



$$\partial_{tt}\varphi + 2\Gamma\partial_t\varphi + [\omega_0^2 + F\cos(\omega_p t)]\varphi + \gamma\varphi^3 = \xi(t), \quad (1)$$



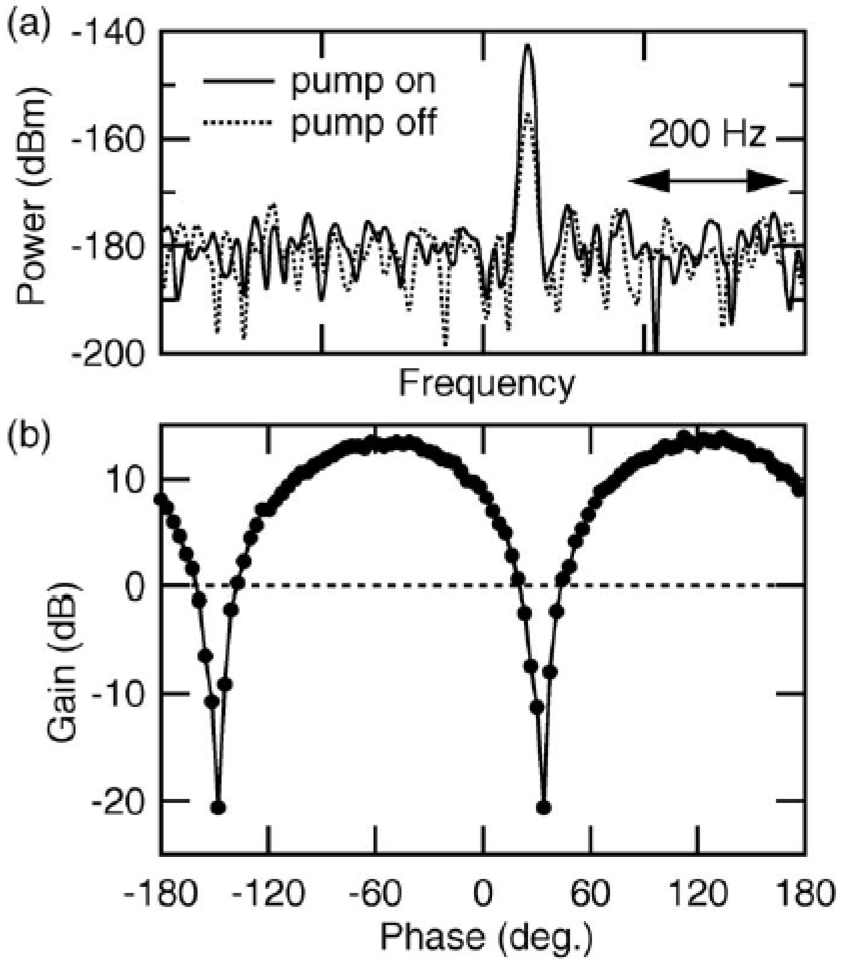


What we expect to see (2) : parametric amplification

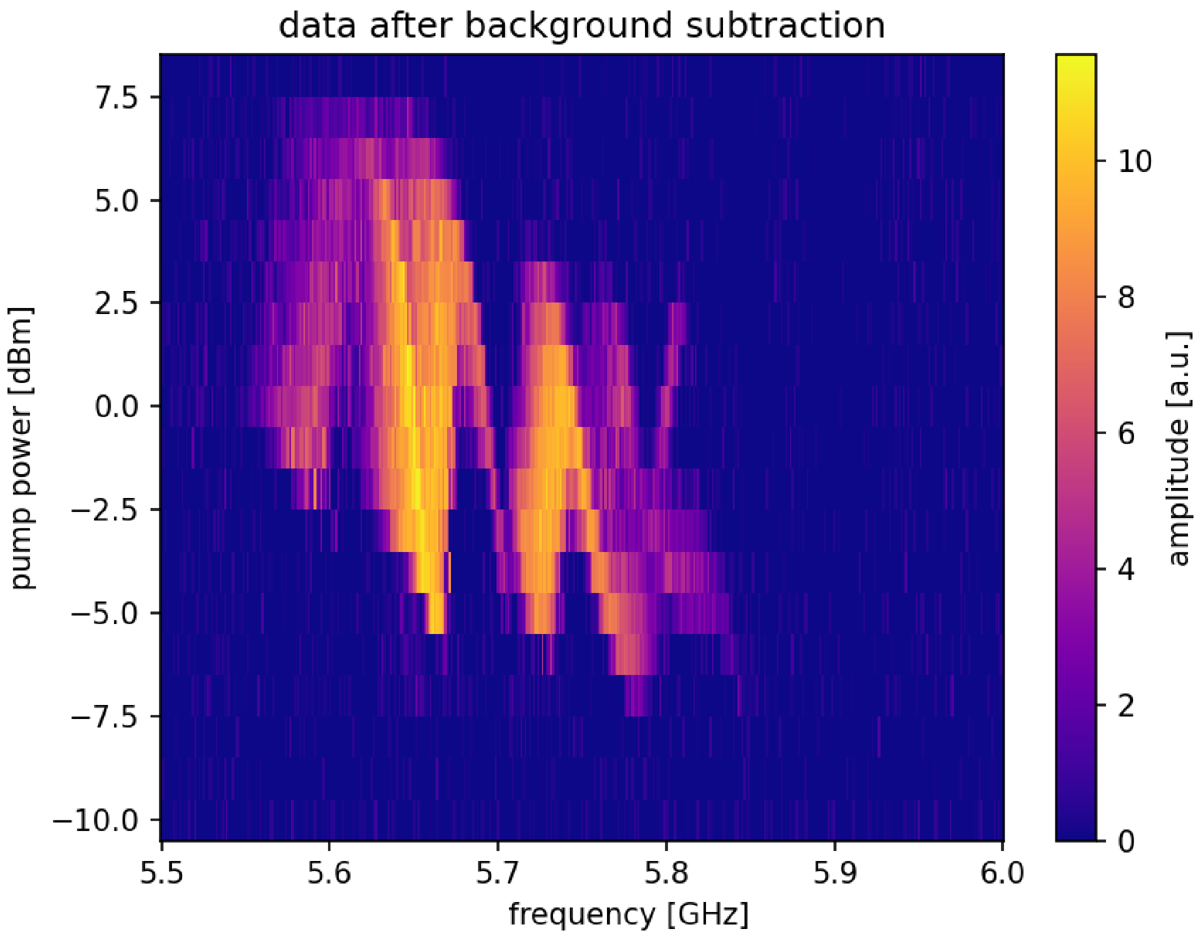
APPLIED PHYSICS LETTERS **93**, 042510 (2008)

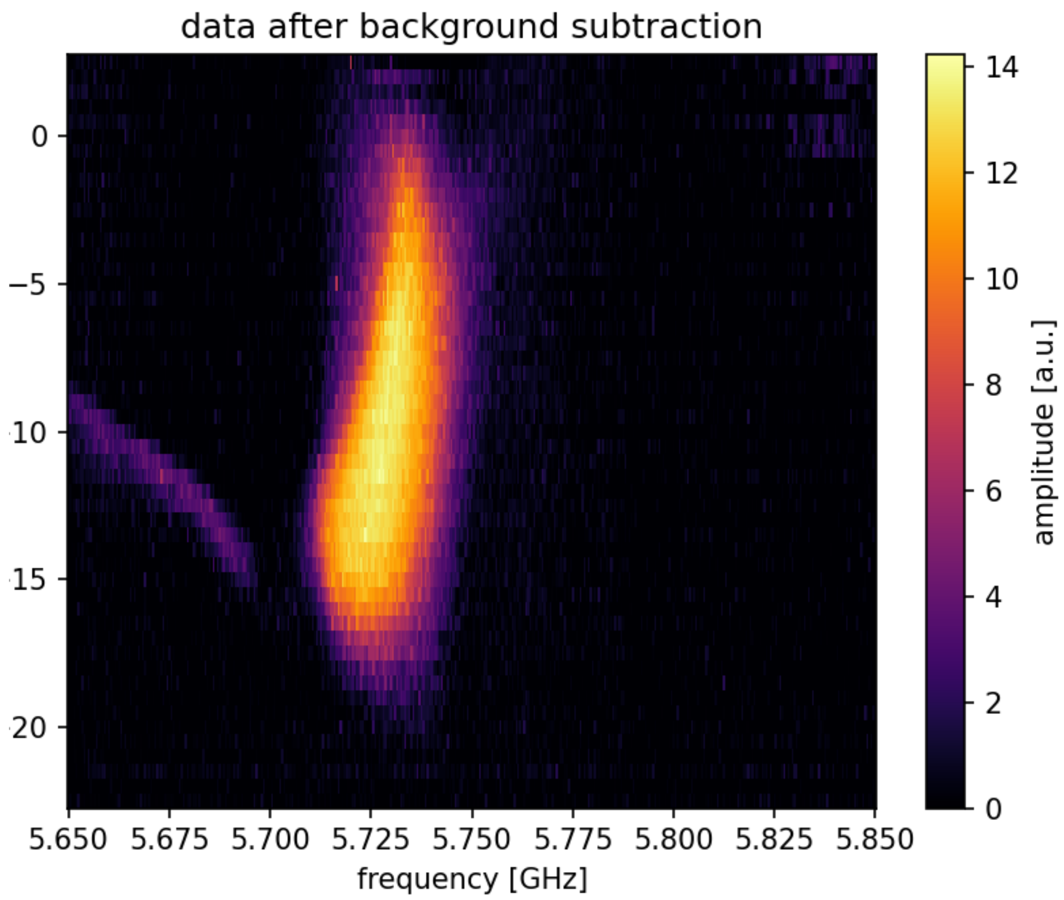
Flux-driven Josephson parametric amplifier

T. Yamamoto,[1,a] K. Inomata,[2] M. Watanabe,[2] K. Matsuba,[3] T. Miyazaki,[4] W. D. Oliver,[5]
Y. Nakamura,[1] and J. S. Tsai[1]



Onset of bifurcation instabilities ?

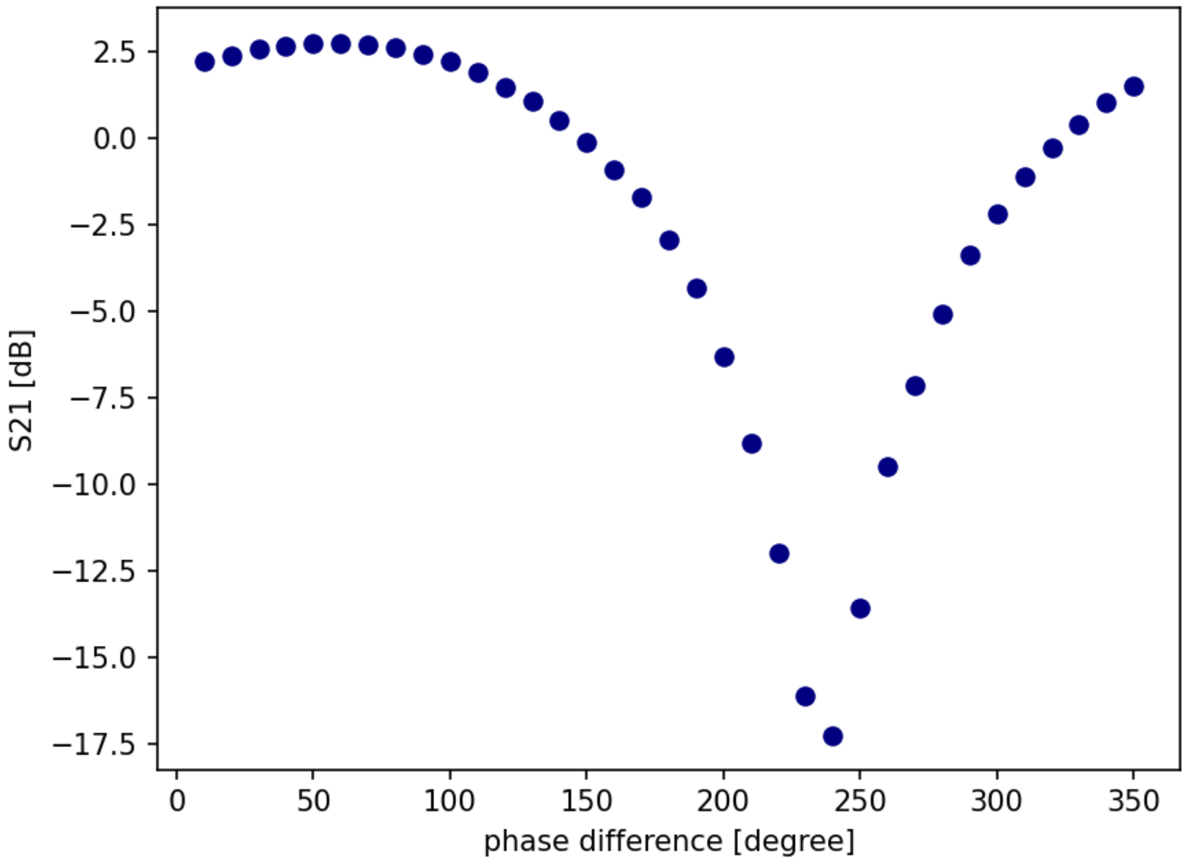


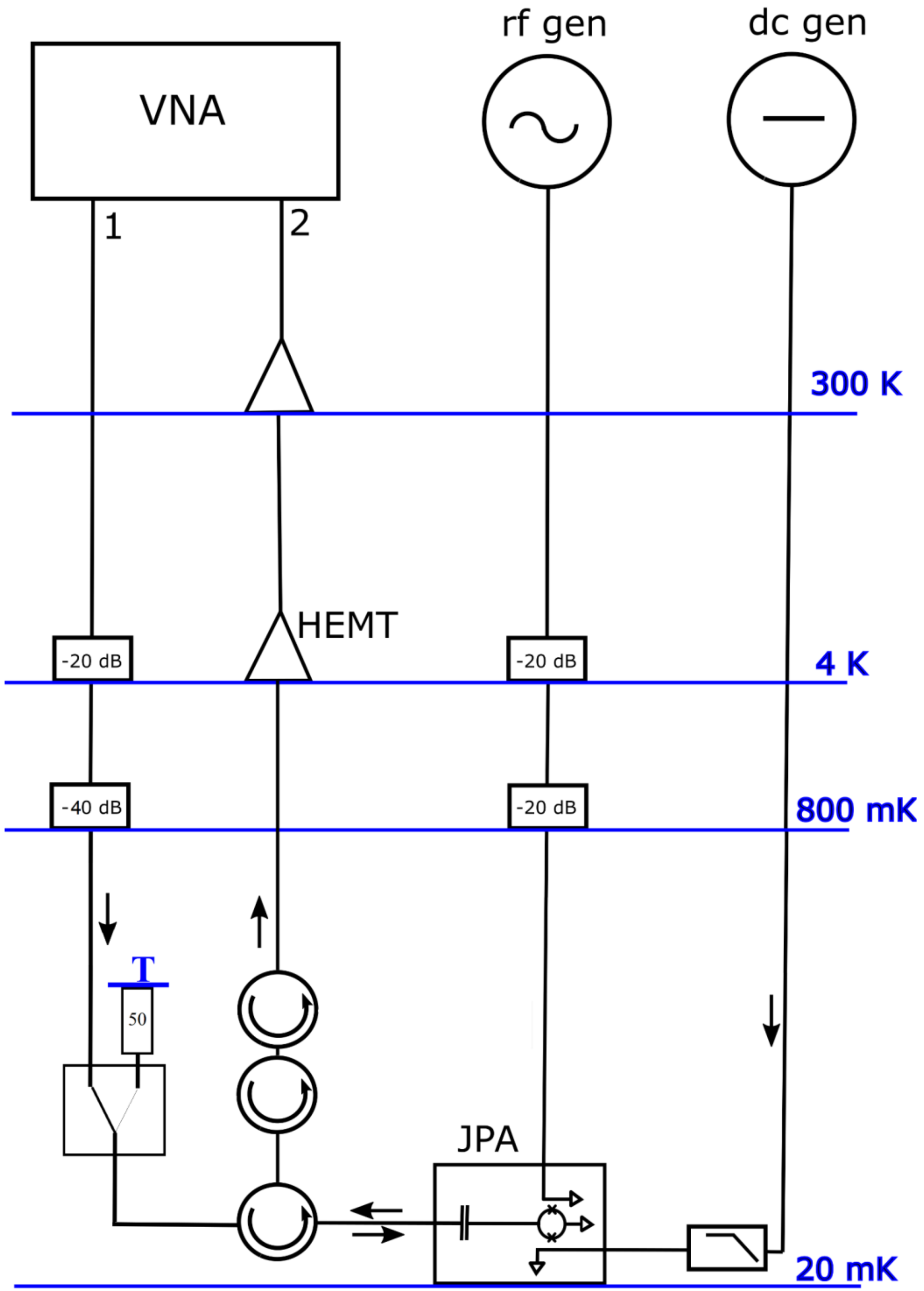


- The effect appears only on very specific flux bias point, where the JPA couples to one (or more) unknown resonances !!
- Except for big region on right plot, no one-to-one correspondence between pump and signal at half-pump frequency !!
- The frequency of the amplification region does not depend on the flux bias point (only shape/threshold does)

Phase sensitive amplification INSIDE «instability» region

Degenerate variable GAIN measured with VNA: Signal frequency = 1/2 pump frequency
(GENERATOR and VNA are synchronized)
Gain reference is uncalibrated !

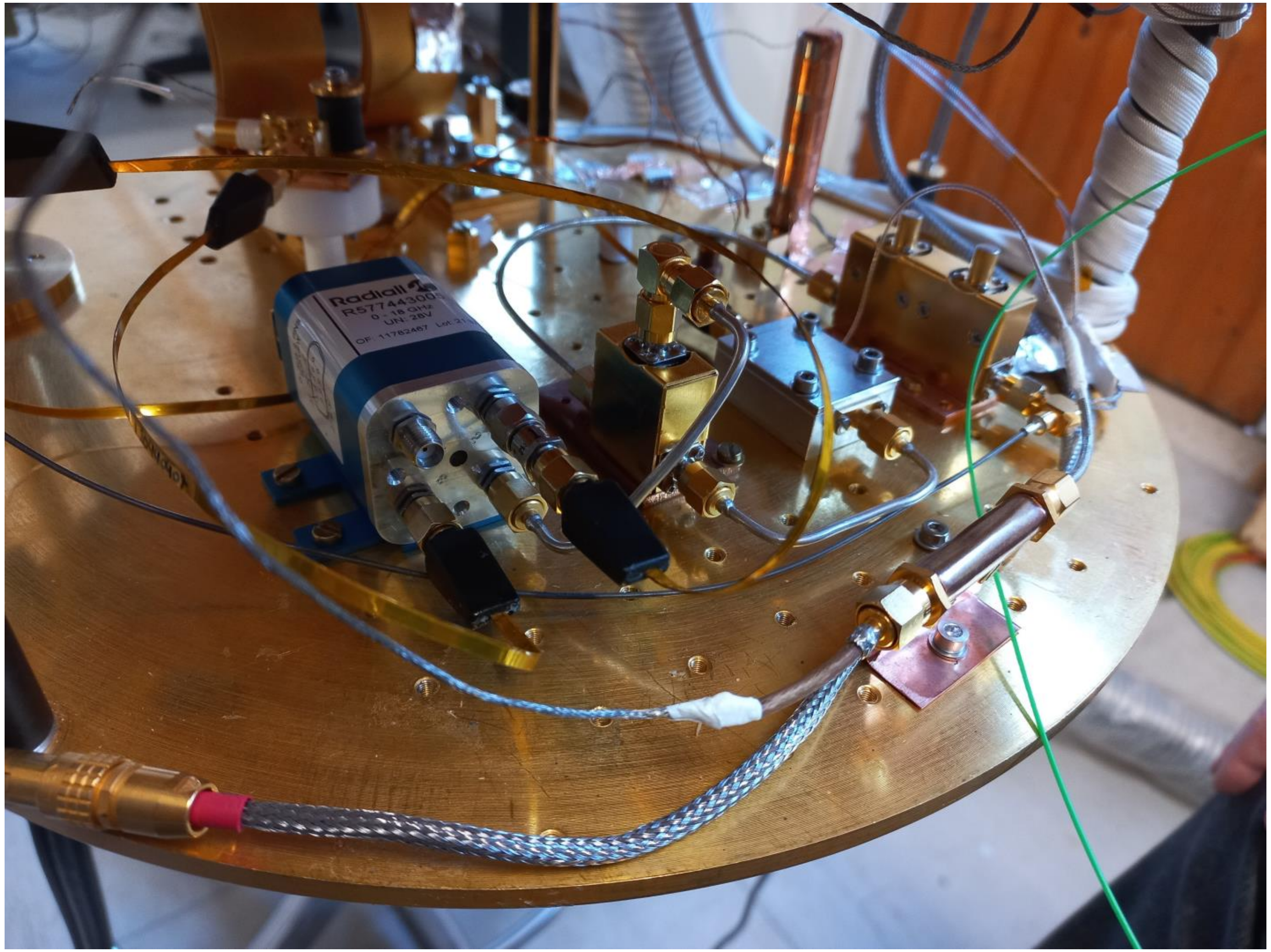


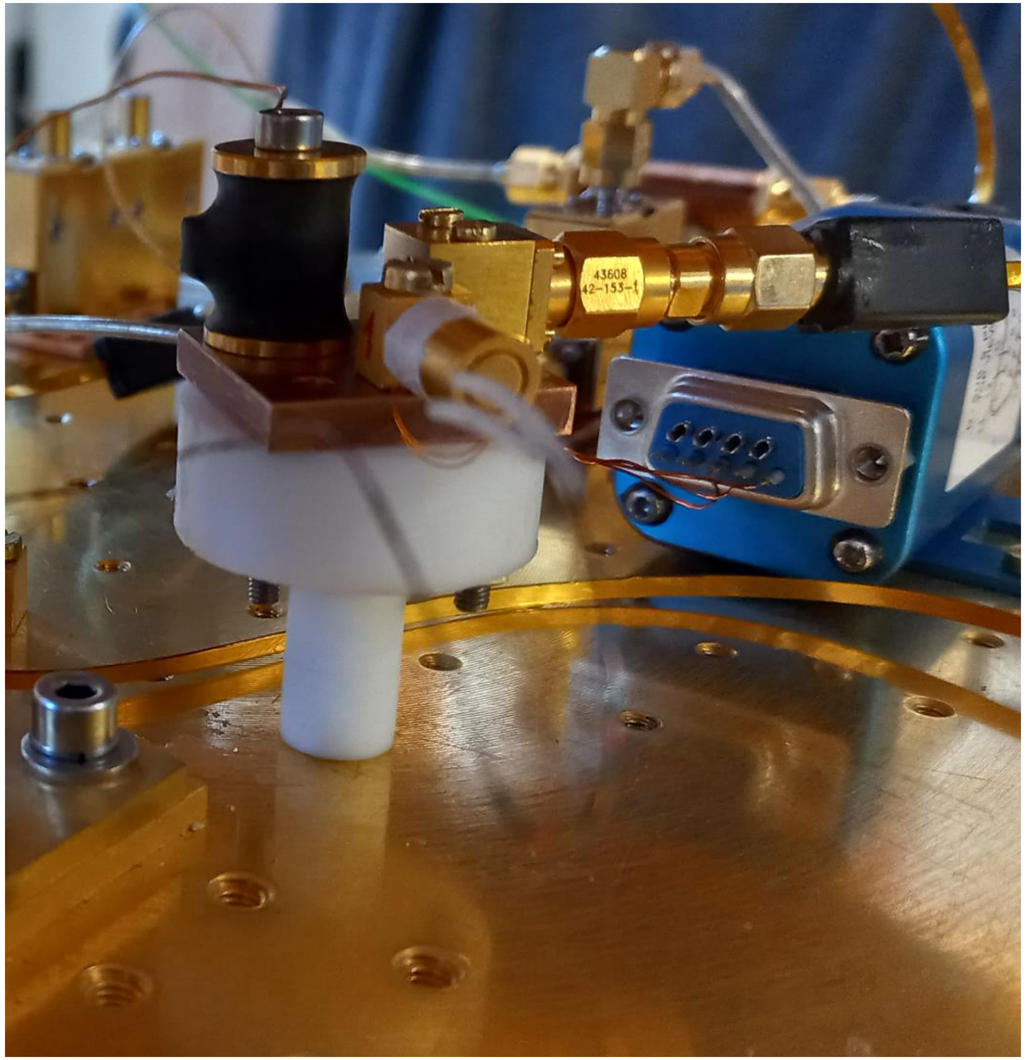


Second cooldown

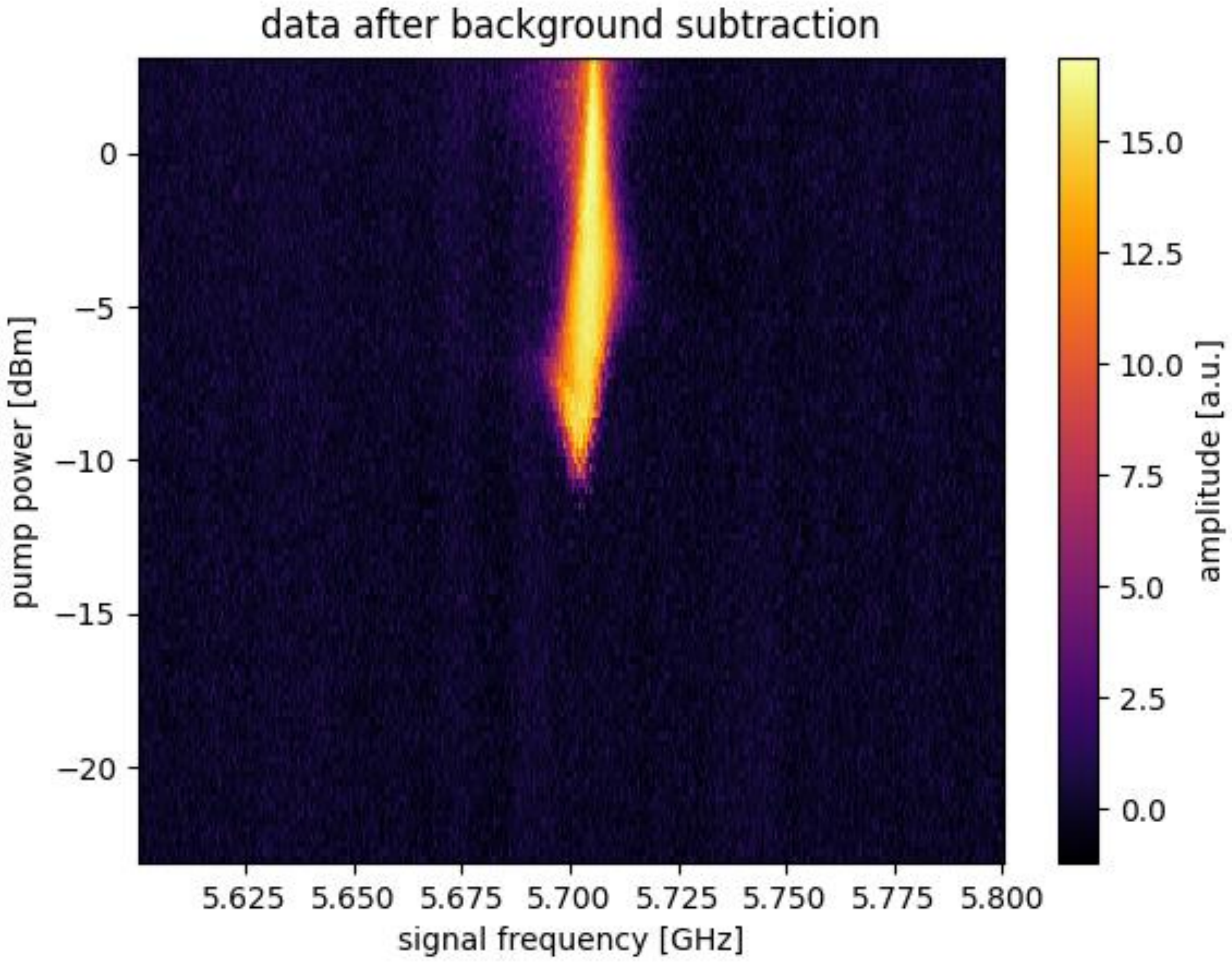
- Destroyed second JPA/resonator on chip (by bonding multiple wires on it)
- Increased attenuation/isolation
- Added a variable temperature resistor for noise calibration with thermal noise

New setup: the calibration noise resistor stage



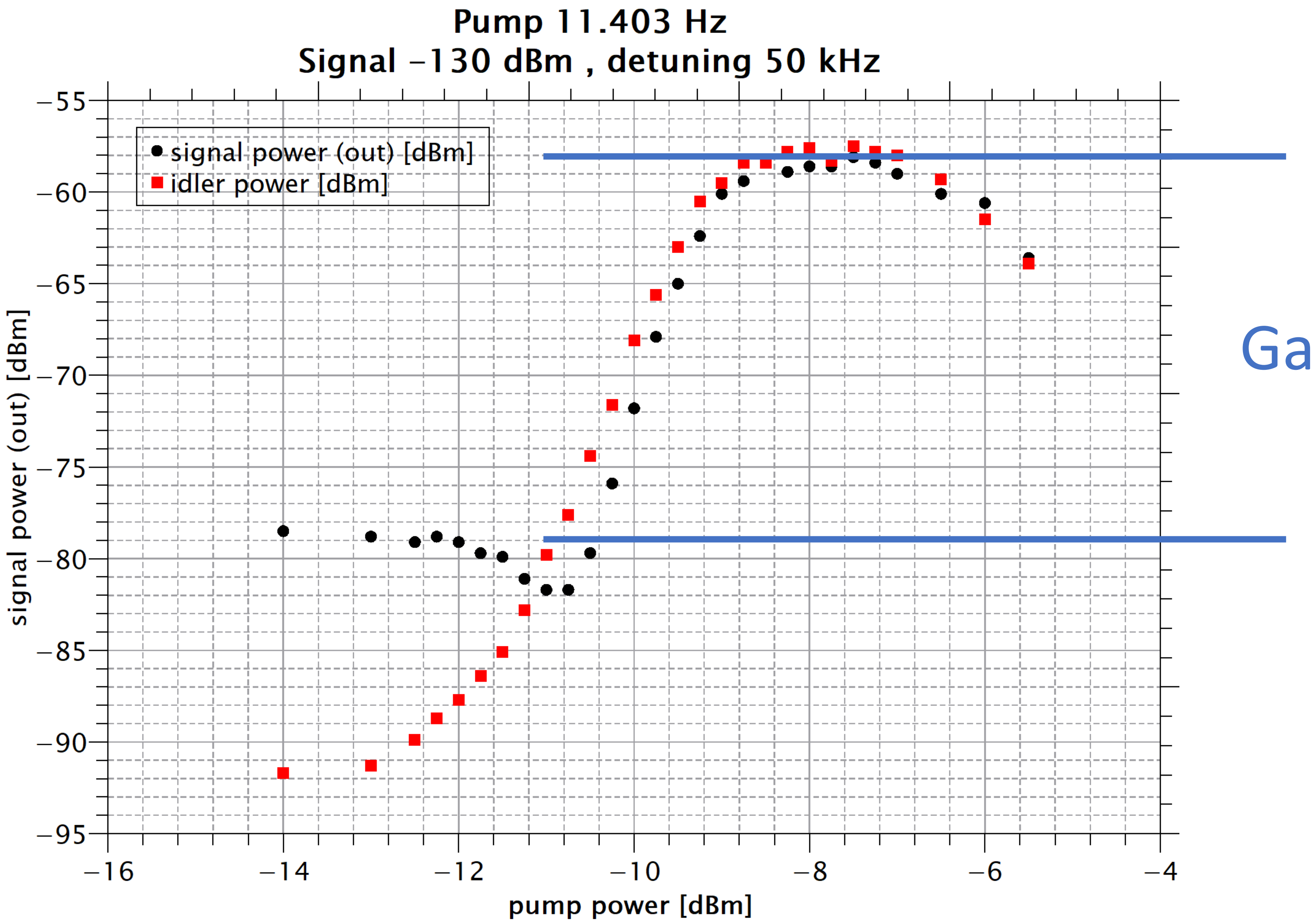


«Onset of parametric instabilities» reloaded



- The JPA still couples to unknown resonances
- Amplification at half pump frequency only close to this region
- The amplification region is narrower than previous cooldown

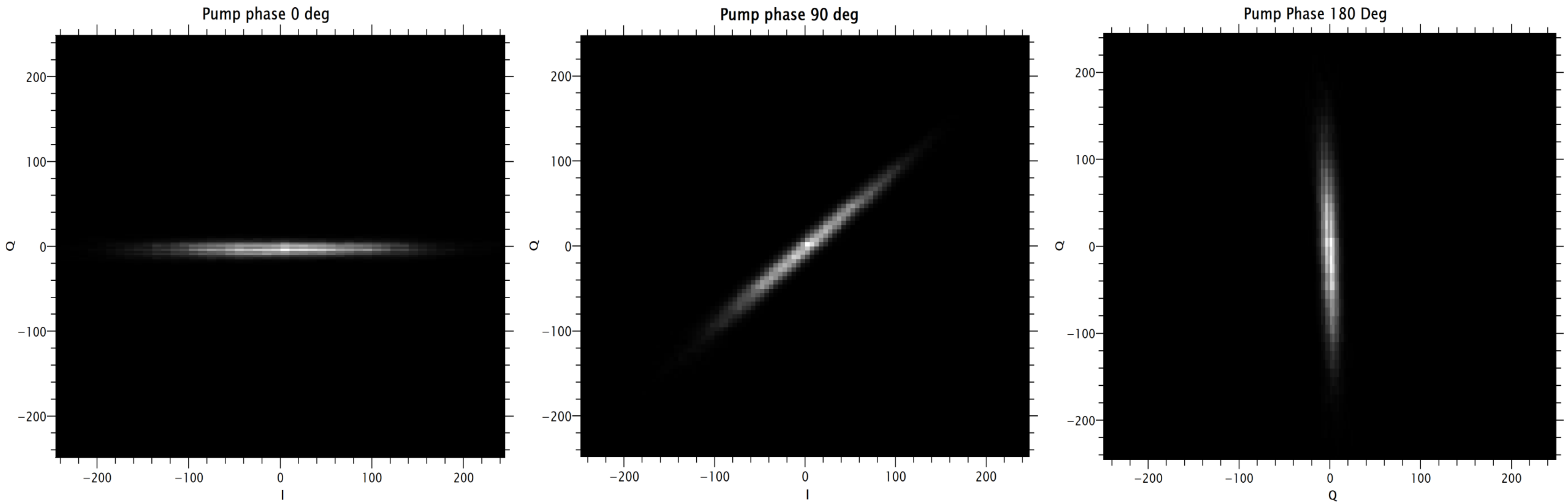
Nondegenerate Gain



Gain ~ 20 dB

Noise Squeezing

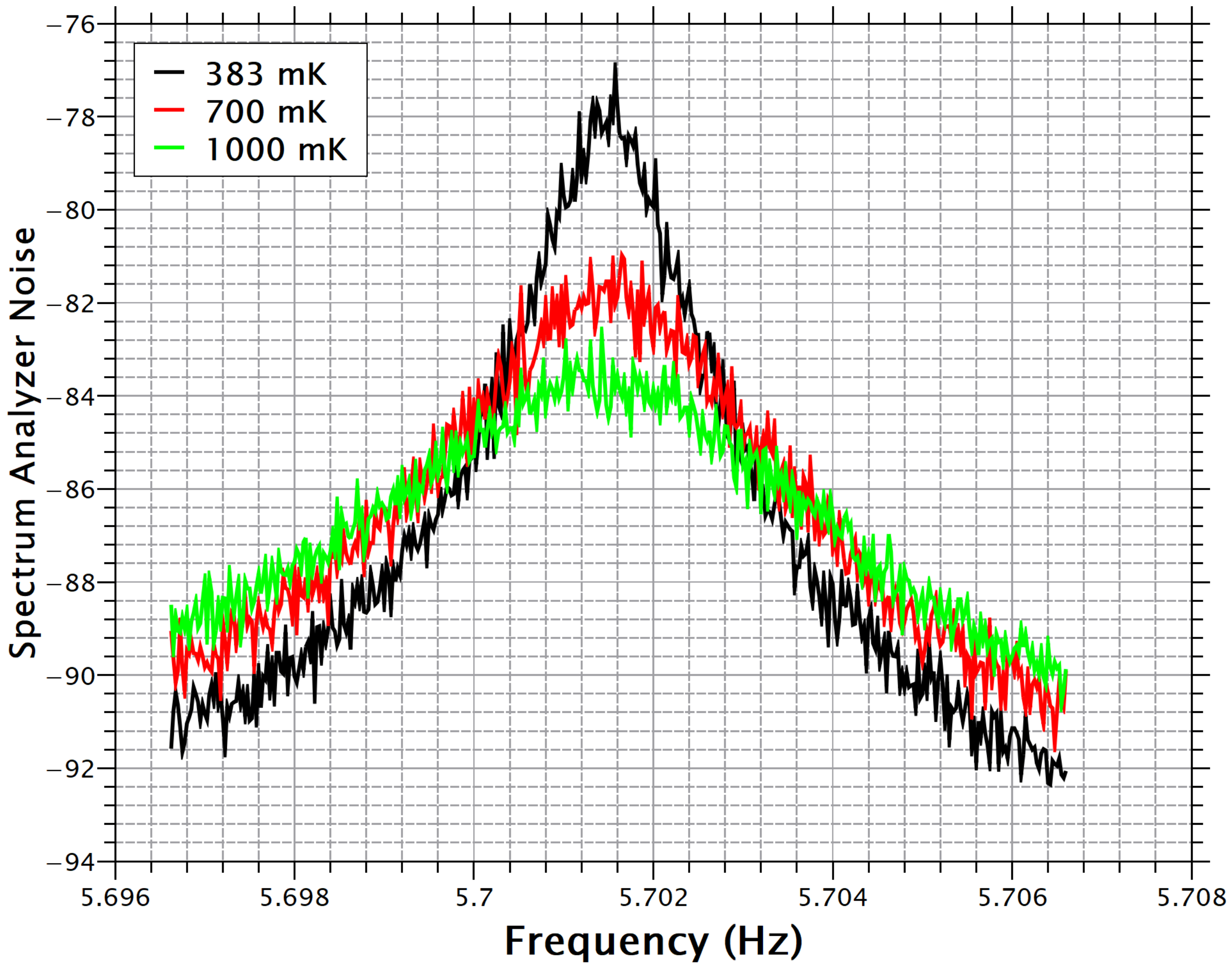
Measure with a mixer , with LO synchronized to ½ pump frequency
Pump 11.403 GHz , -8.5 dBm
Noise integrated over 0-30 kHz



Squeezing factor = noise max/noise min = 14
(never a bifurcation!)

Failed attempt of Noise calibration

Resistance stage works, apart from T saturation at 400 mK (due to an excess heat load)



- Only temperature of the resistor is changed
  Max MC temperature variation ~2 mK
- We have done similar measurement by changing the MC temperature over 70 mK. No change in the JPA response!

JPA response depends on the thermal noise!
Saturation effect !?!

(NB Integral of curve roughly constant)

(partial) conclusions

- Flux to Frequency curve OK

- Observed **instability-like region is not instability**! Never see a bifurcation

- In the sweet spot the device **works roughly as a JPA**

  Phase-sensitive amplification in degenerate mode
  Signal-Idler amplification in non-degenerate mode
  Noise Squeezing (with large squeezing factor!)
  Very low saturation power (?)

NOT UNDERSTOOD:

- What are the unknown resonances ?
- Why doesn’t the JPA never reach instability/bifurcation?
- Why don’t we see any amplifier feature far from the sweet spot?