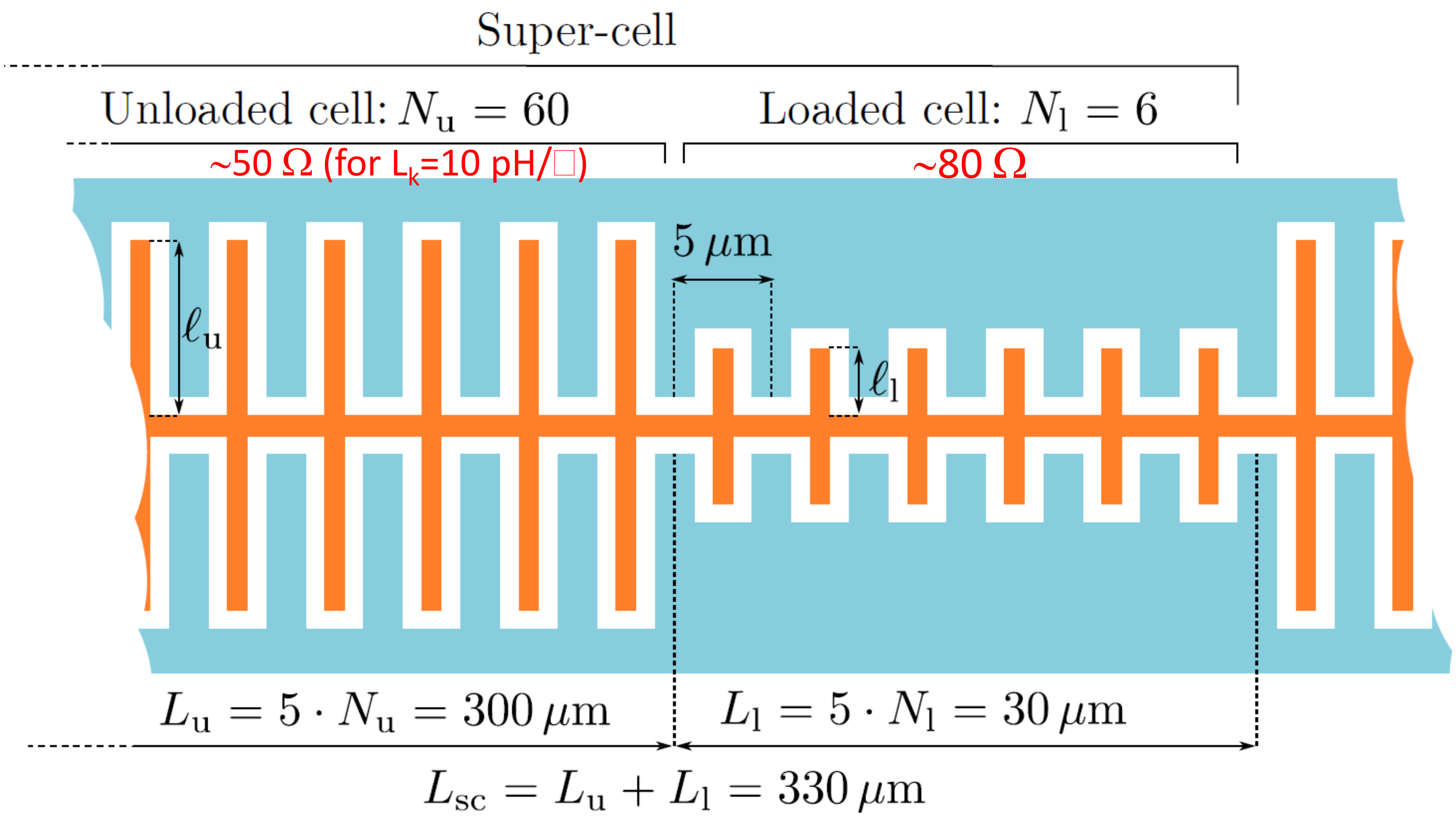
Initial tests of short KIT/DTWKI prototypes

Andrea Vinante - Dartwars meeting Feb 6, 2023

Outline

- First tests of (short) prototypes of KIT amplifiers
  - Design/production in FBK
  - Transmission measurements & stopbands
  - Nonlinearity & critical current
  - 3W mixing
- Status of WP3 & 2023 outlook

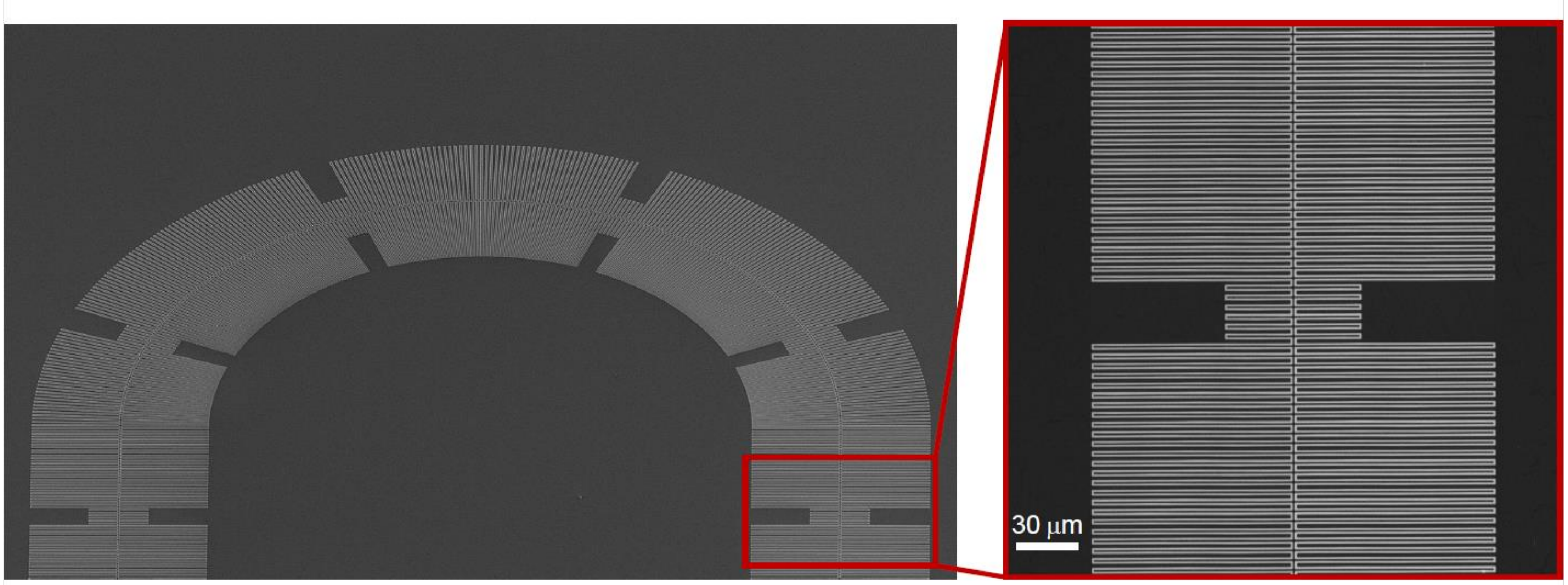
KIT Prototype Design (~ NIST design, Malnou et al, PRX Quantum 2021)



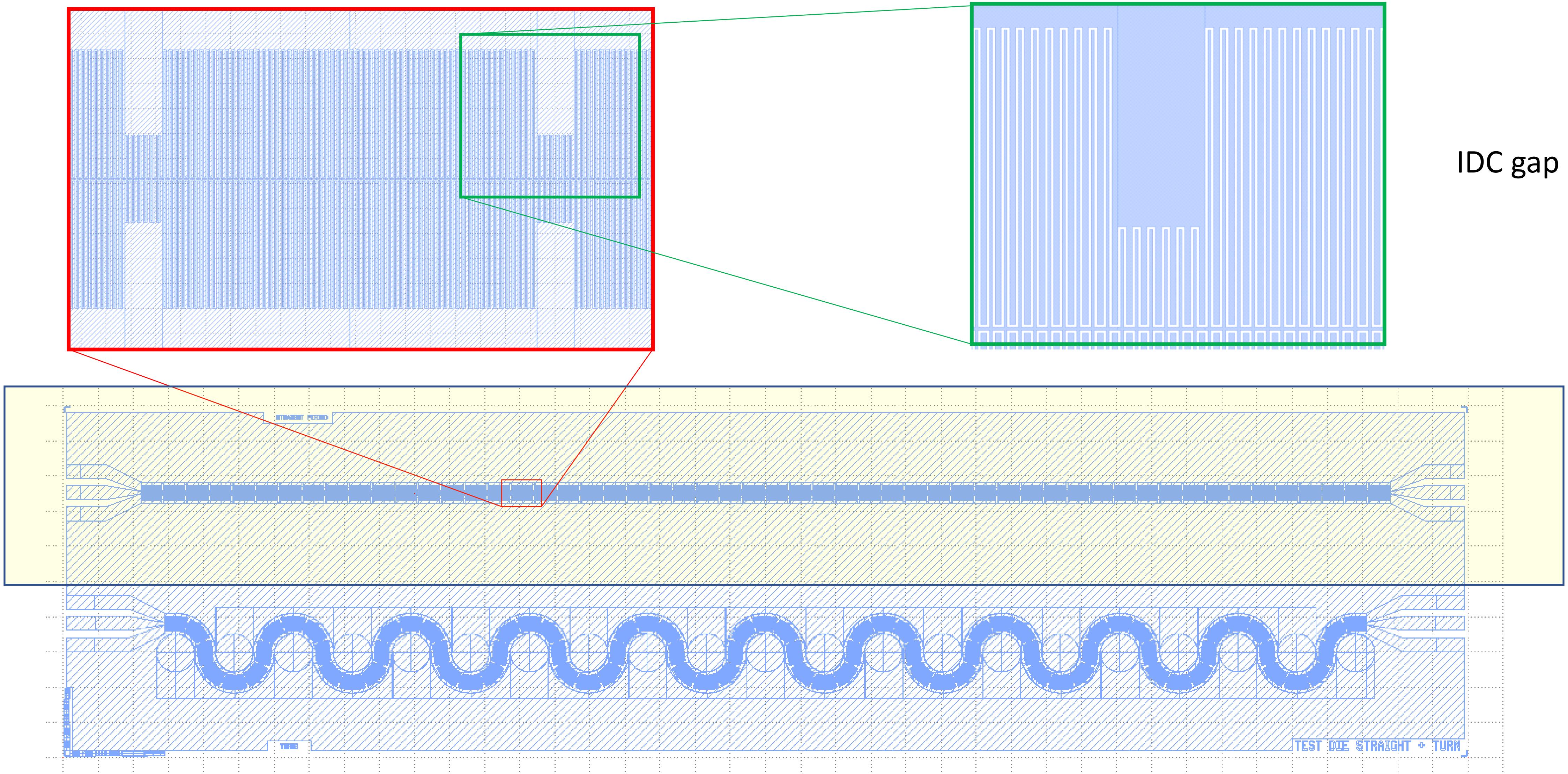
- Line is dispersive
- Periodic loading $\Rightarrow$ stopband engineering (enables phase matching)

Production in FBK

- June 2022: First attempt. Problems with material & lithography (no electrical continuity/ shorts to ground)
- July – Dec 2022: Tuning and control of material properties
- Jan 2023: Second fabrication run



KIT Prototype Design: real device under test



IDC gap = 1 μm

- Straight artificial line: 54 Supercells, length 17.8 mm (Final device ~1000 Supercells!)
- Two devices per chip ➡ Chip grounding is not optimal

Electrical tests at room temperature

- Requires quite some care.

  High resistance. R≈60 Ω/□ × (18000 □) ≈ 1.1 MΩ

  Needs very low excitation current (<< 1 μA) to avoid discharge through air

  Very long gap perimeter ~ 1.5 m ⇒ parasitic conductance to ground practically unavoidable at room

  For the long (final) device everything is scaled up by factor 18.5 !

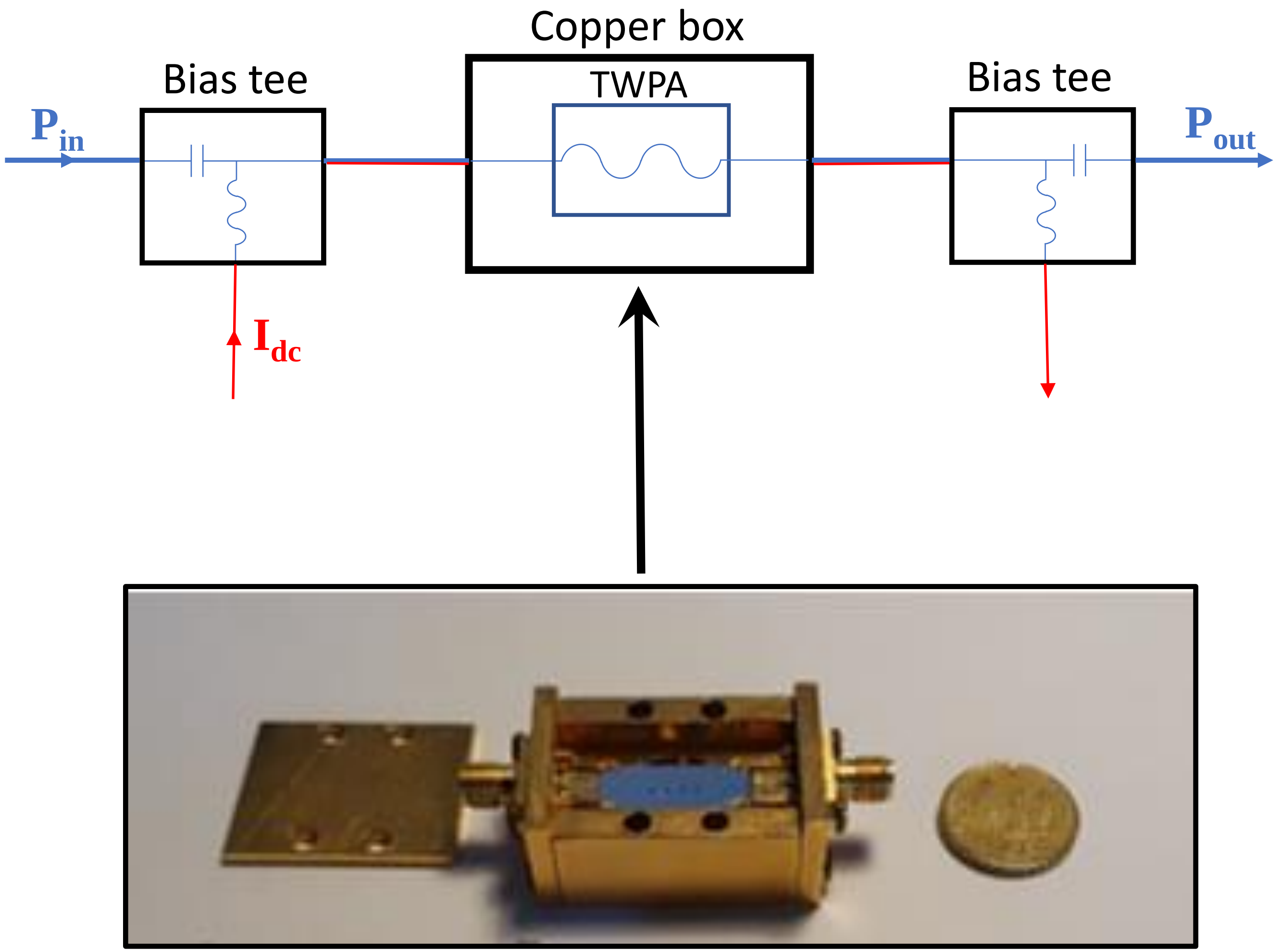
- Measurements consistent with substantial integrity for most devices (VERY GOOD NEWS!)

  Resistance to ground in short devices ~ 10 MΩ

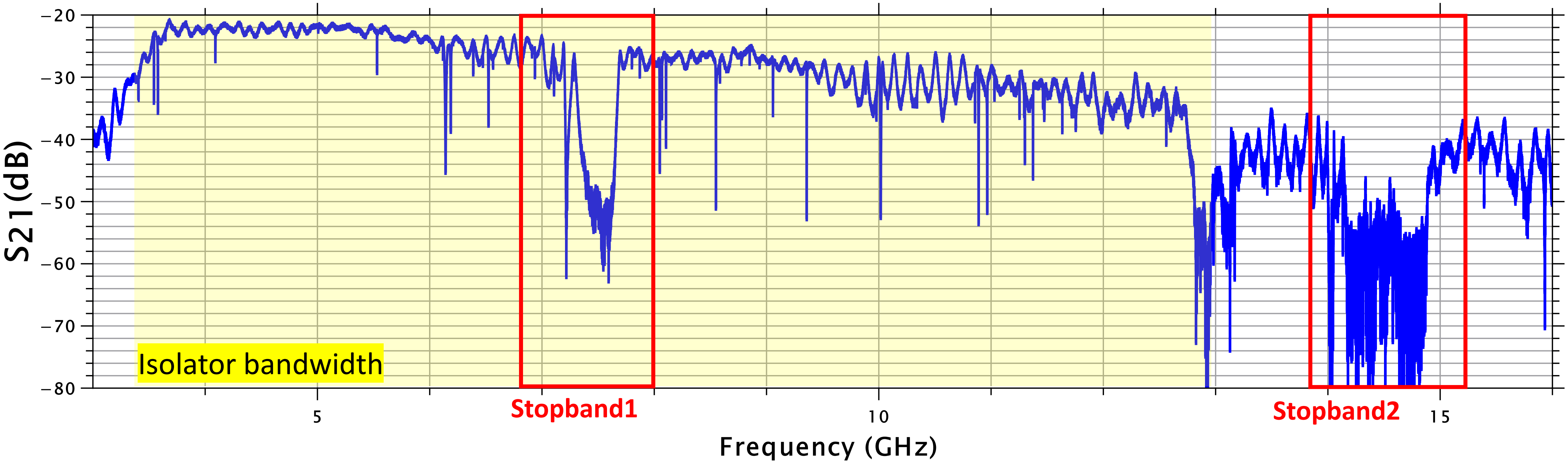
  Could be explained by parasitic conductance through air & oxide or through surface adsorbate in the gap (this would be frozen or uneffective at low T)

  Real shorts to ground cannot be fully ruled out through simple room T measurements

Cryogenic measurement scheme

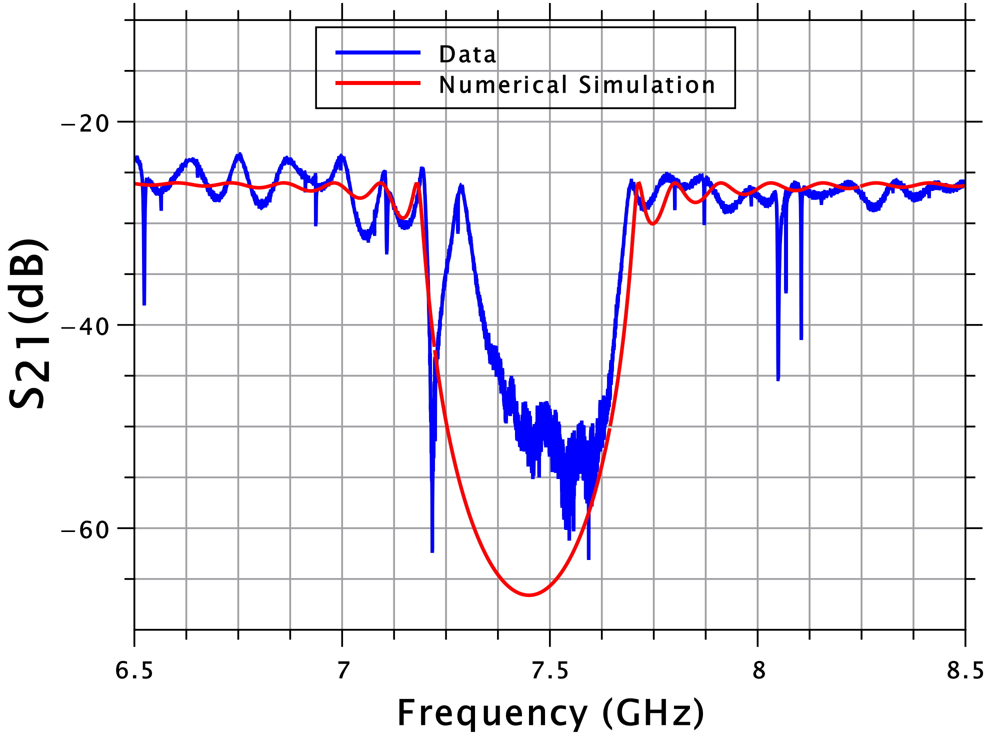


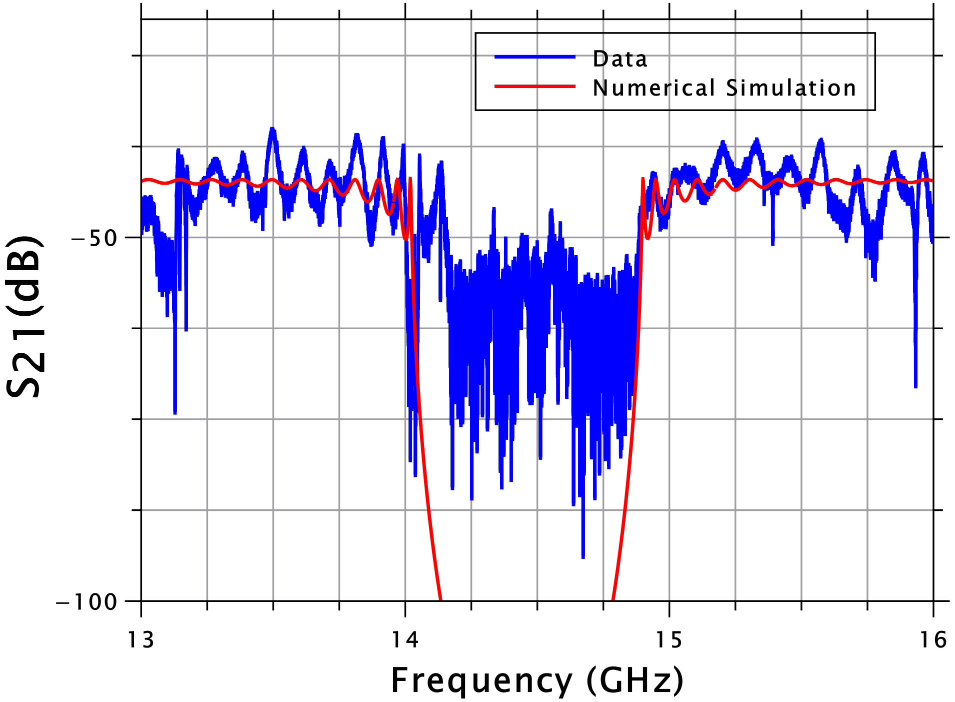
rf transmission (no dc current)



Ripples, but not so bad. We should not be much far from 50 Ω !

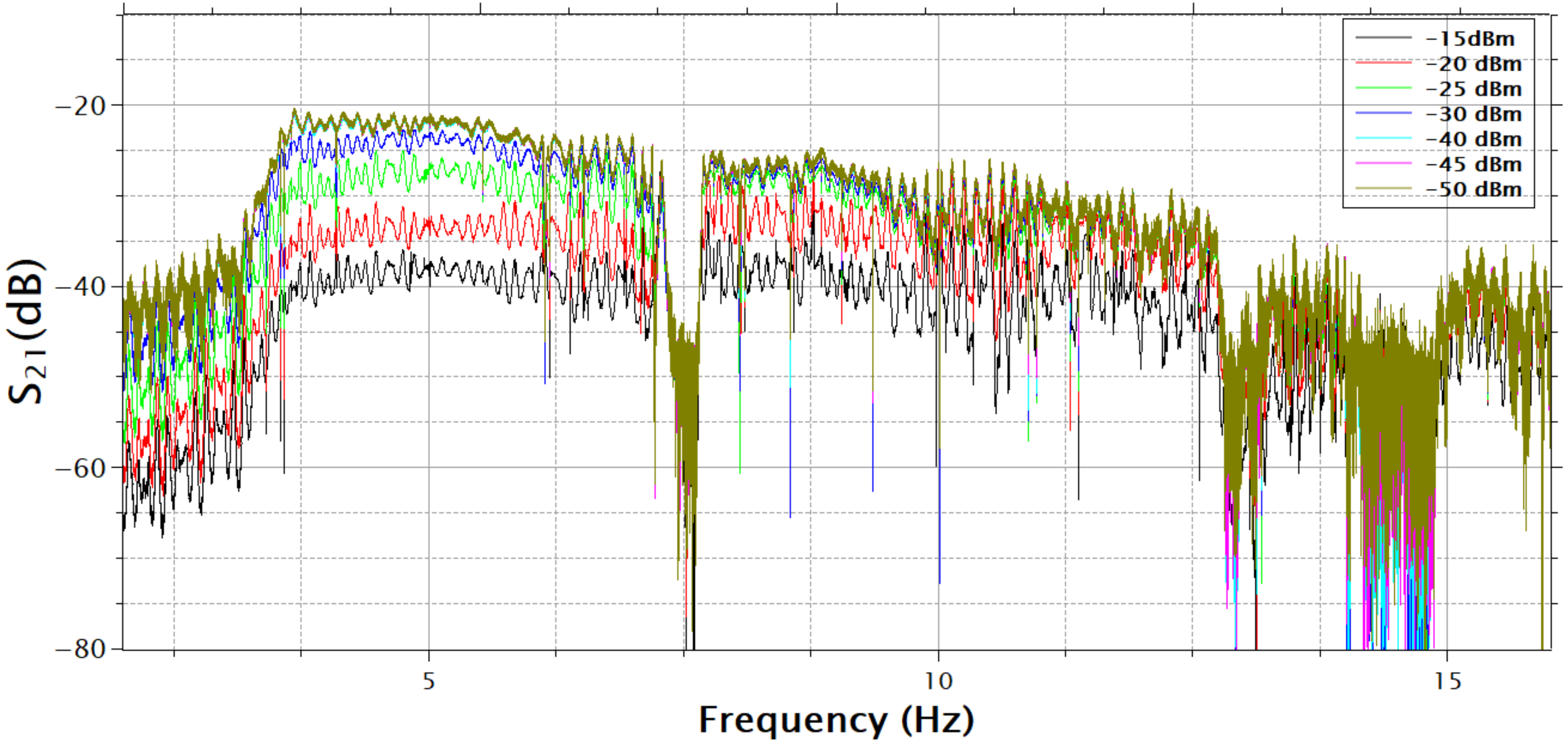
Stopbands





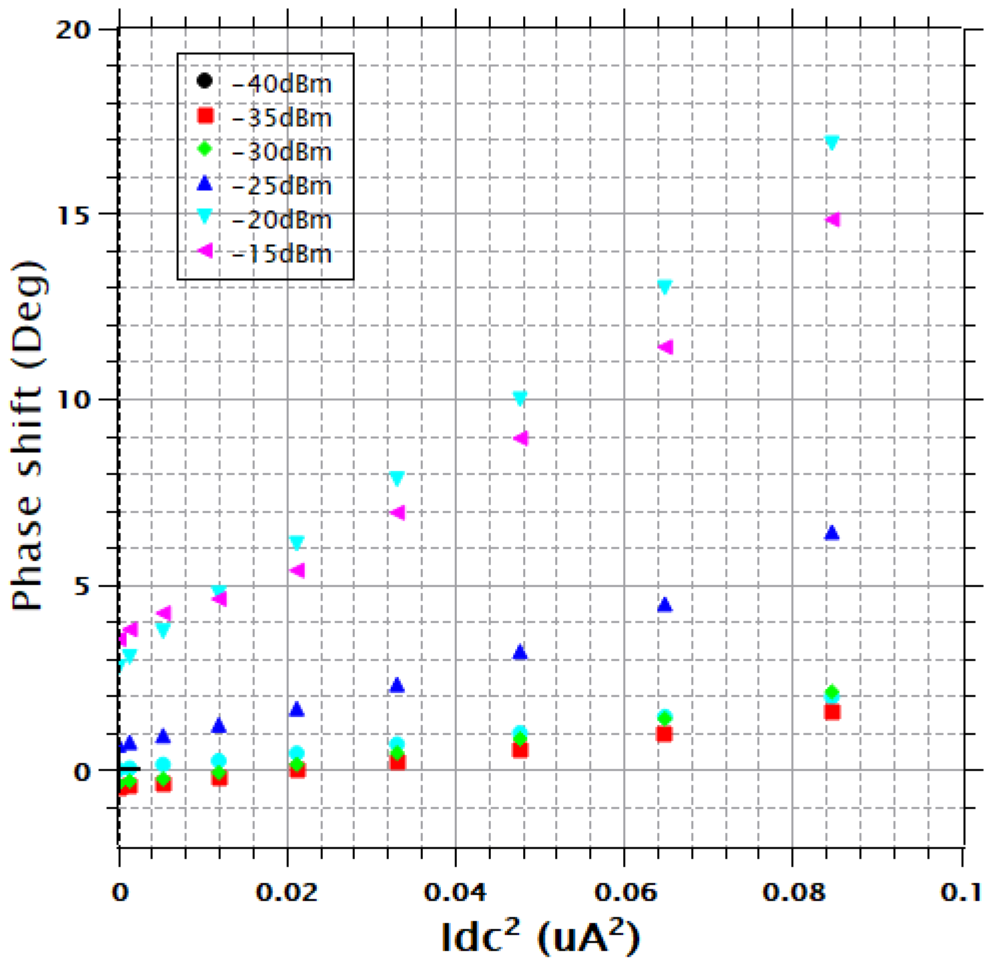
- Simulation (Mathematica) using lumped ABCD-matrix method, following Malnou paper
- Requires the product $C*L_k$ (per unit length) a factor 1.27 larger than in Malnou
- If C is the same $\Rightarrow L_k \approx 12.5$ pH/□

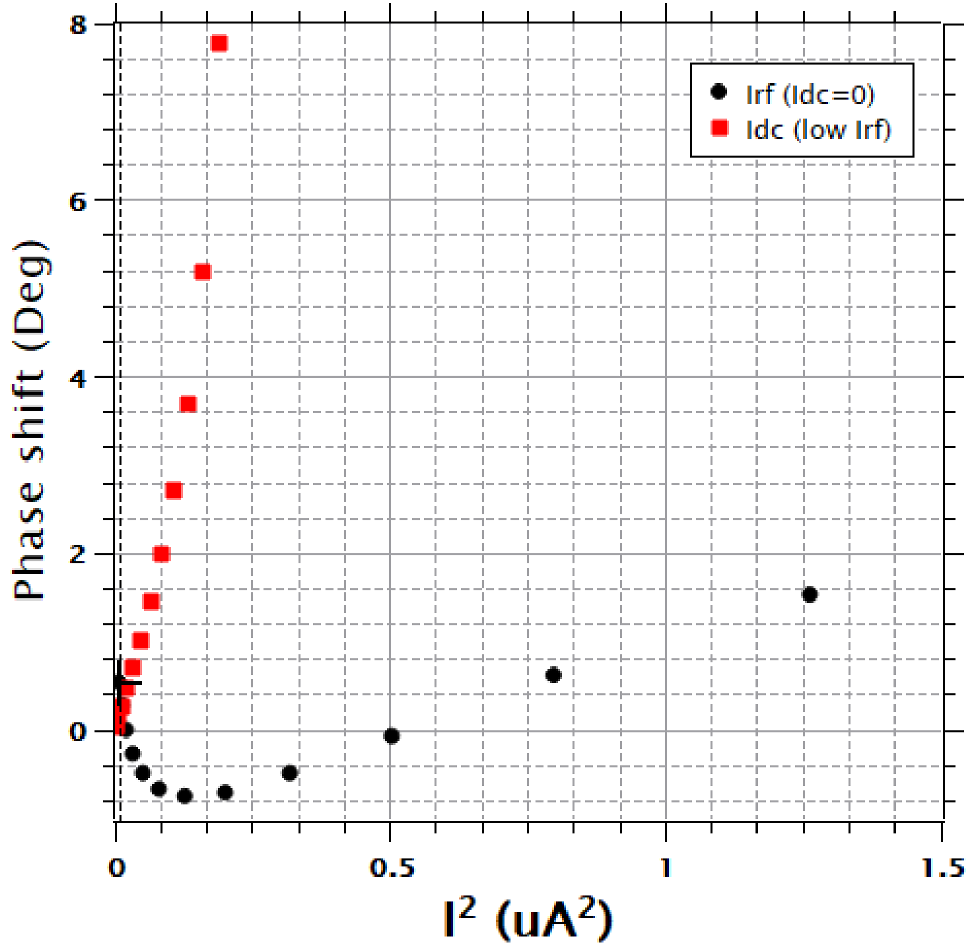
Power dependence



- True power @device is ~ -50 dB lower ⇒ Transmission strongly suppressed already at -70 dBm ($I_{rf} \sim 1\ \mu A$!)
- Spurious peaks are mostly not suppressed ⇒ not related with the artificial line!

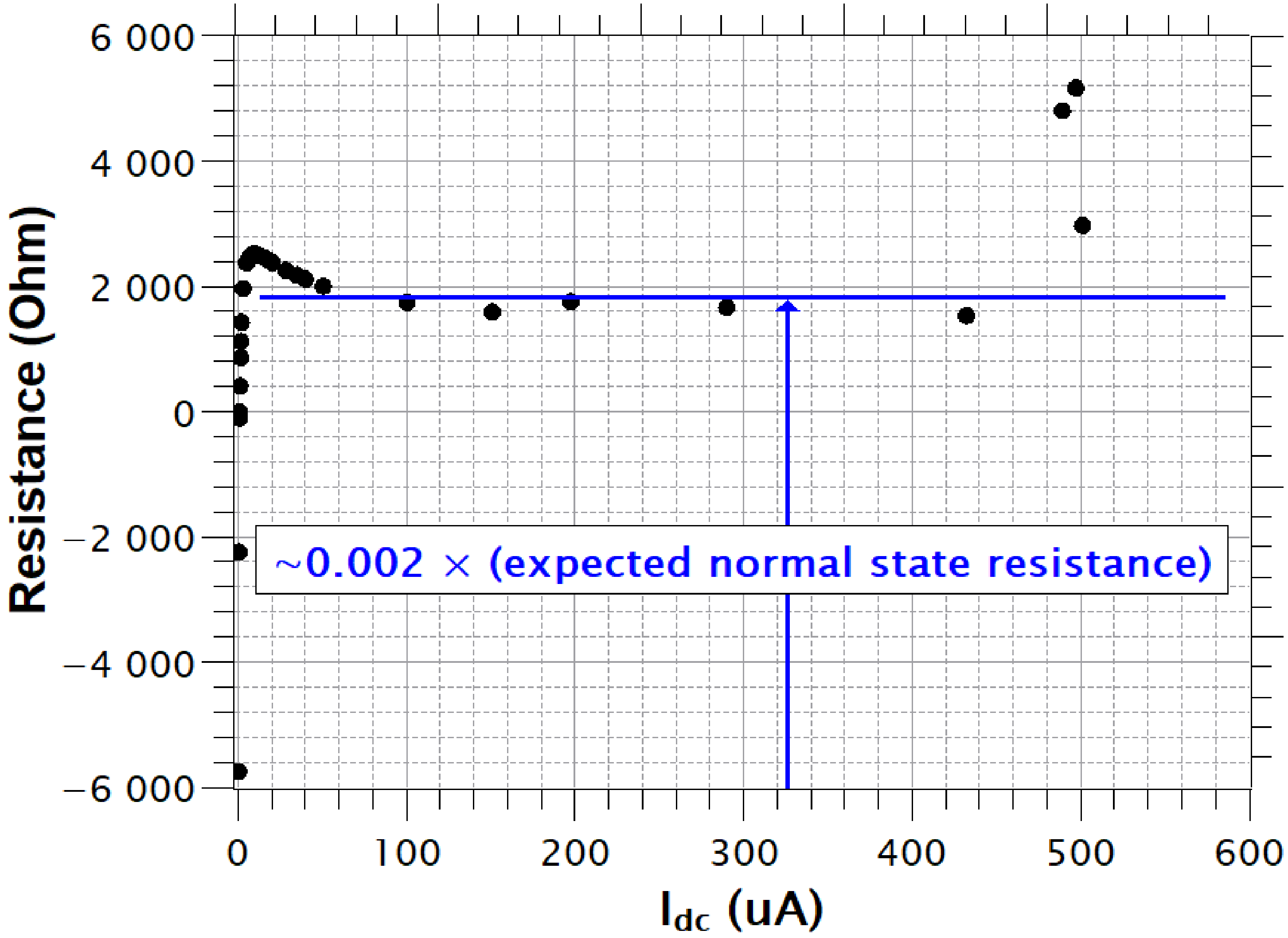
Nonlinear phase shift





Nonlinearity is indeed on ~μA scale !!

Critical current measurement (through bias tees)

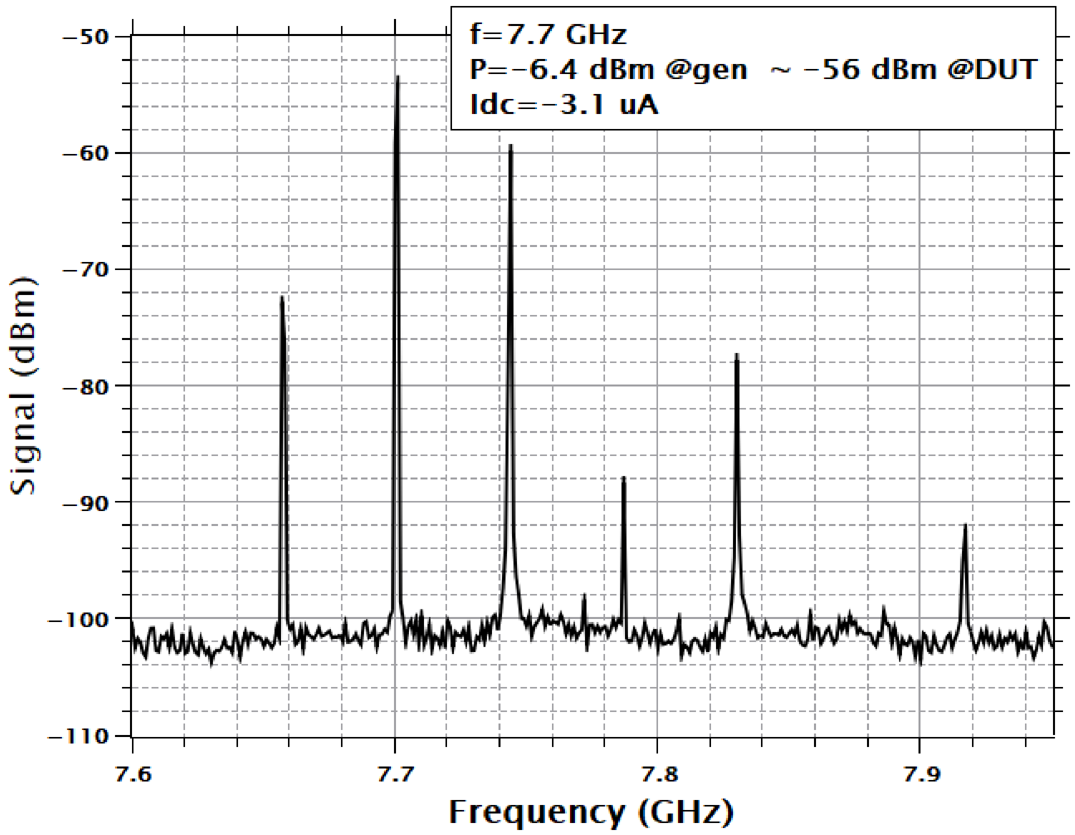


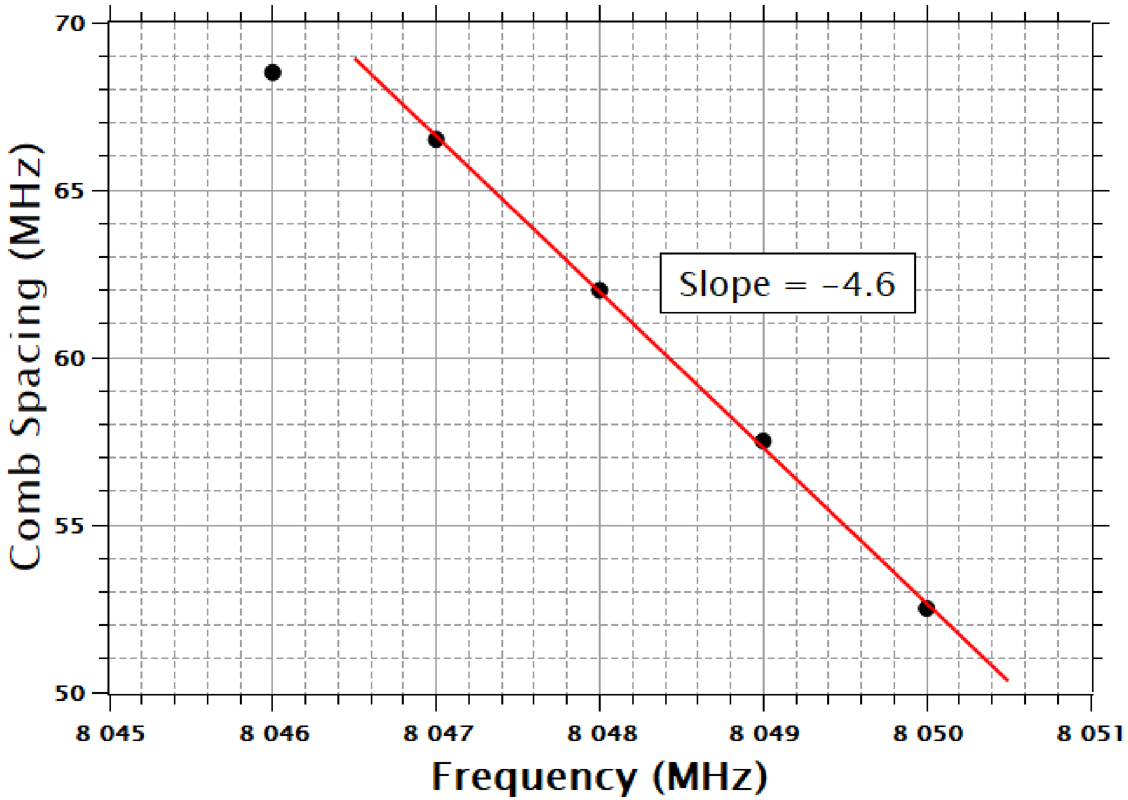
Two transitions:

- 500 μA: close to expectations
- ~ 1 μA: mistery

Could indicate a weak spot in the line, that behaves as a weak link/JJ ?

Pump-only comb generation (?)

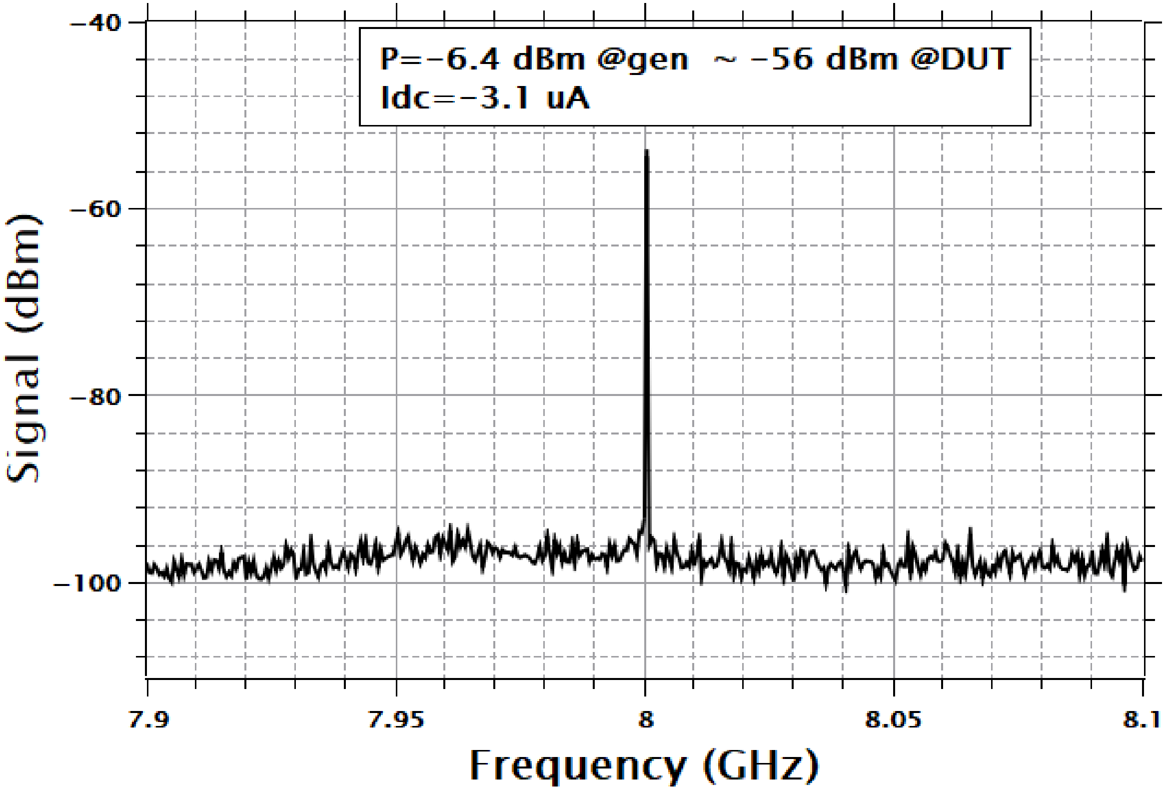




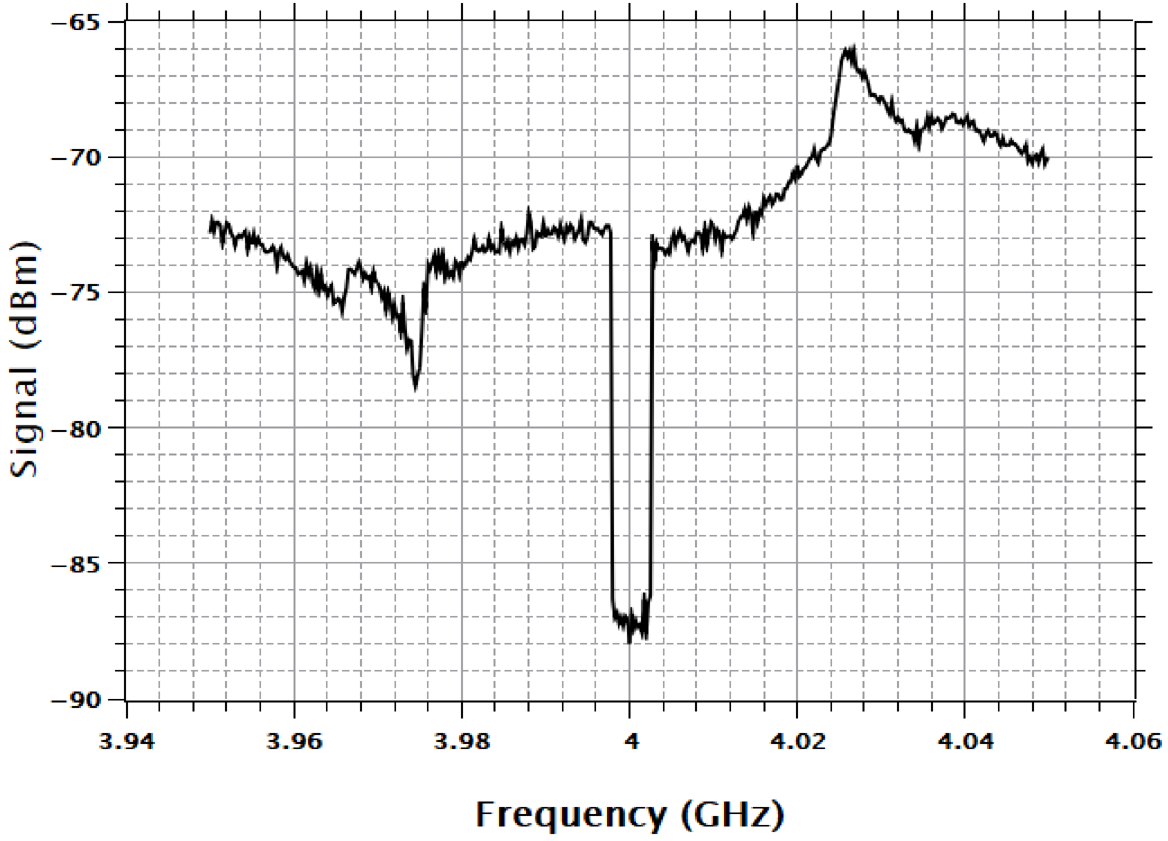
Instrumental artifact or something weird going on in the device?

3-wave Mixing

Pump fixed at 8 GHz (no comb !)



Signal sweep 3.94-4 GHz



Idler amplitude ~ Signal amplitude
(Expected for G $\gtrsim 2$)

Outlook

- Extensive screening of a lot of devices at 4 K
  (liquid helium is again available)
- Select devices that behave well (high Ic, featuring stopbands …)
- Further tests at low T

STATUS of WP3

Working Package Number:	3	**Start Date or Starting Event**				
WP Package Title:	DTWKI Test and Characterization, and read out demonstration with microcalorimeters					
Participant short name:	LE	MIB	TIFPA			
Person/month per participant	10	18	41			
WP Leader	Andrea Vinante (TIFPA)					

Objectives: the goal of this WP is the full test and characterization of all the DTWKIs developed during the project and the demonstration of quantum limited noise read out with TESs and MIKDs.

Description of work

Prototype devices of the DTWKI developed in WP2 will be experimentally characterized at temperatures below 300 mK. A scheme of the measurement setup is reported in Figure 3. These measurements will provide feedback to the WP1 and WP2 in order to improve the design and the fabrication. TESs and MKIDs will be readout by coupling the resonator arrays to the TWPA input and their response will be studied with photon calibrations. Transmon qubits coupled to magnetostatic modes in Yttrium Iron Garnet (YIG) and read out by DTWKI will be tested at INFN-LE.

Tasks Description

Task 3.1: Set up of the experimental instrumentations (M1-M6)
Task 3.2: Experimental characterization of the performances of produced DTWKIs (M12-30);
Task 3.3: Test of produced DTWKIs and read out demonstration with detectors (M24-36);

Role of participants

- INFN-MIB and INFN-TIFPA will test and characterize the produced DTWKI amplifiers;
- INFN-MIB will perform the read out demonstration with TESs;
- INFN-MIB and INFN-TIFPA will perform the read out demonstration with MKIDs;

Deliverables

D3.1: Setup of the experimental instrumentations (M6) ✓
D3.2: Report on the DTWKI characterization (M18/M30) ✗
D3.3: Report on the on the read out demonstration with DTWKI (M36) ✗

- Next months:
  Screening at 4.2 K
  Select good devices
  Characterization

Points to be discussed

- Who is available for testing?
- Packaging for final devices?
- Task 3.3 ?