Helmholtzzentrum für Schwerionenforschung GmbH

FAIR

Beam Measurements of a Palmer Pick-up for the Collector Ring of FAIR

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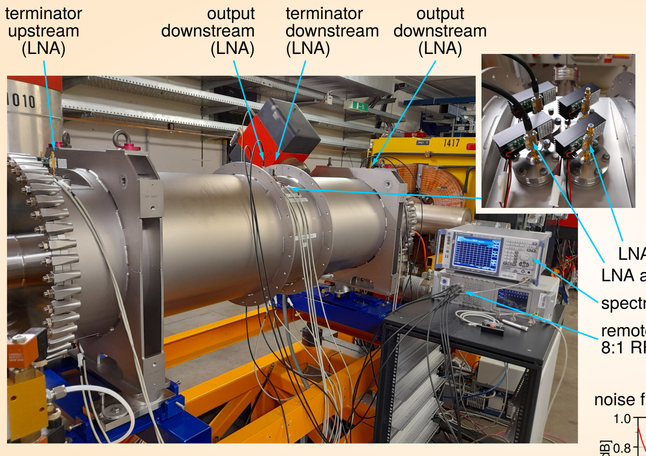
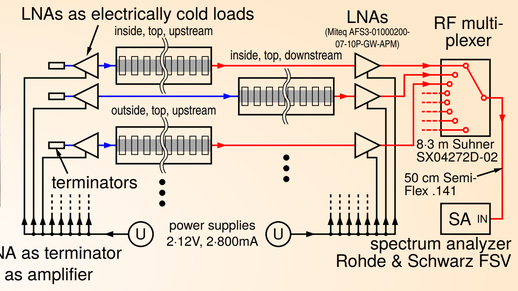
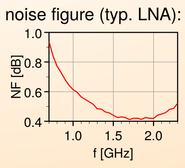
Measurement Setup at the Cooler Synchrotron (COSY) of FZJ





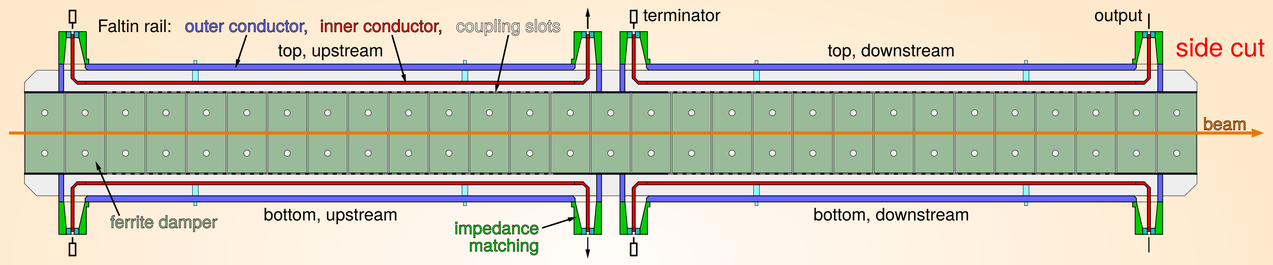
- Palmer Pick-up for the **C**ollector **R**ing (CR) of FAIR installed in the **Co**oler **Sy**nchrotron (COSY) of the **F**orschungs**z**entrum **J**ülich (FZJ)
- **l**ow **n**oise **a**mplifiers (LNAs) installed directly on the vacuum feedthroughs
- spectrum analyzer, RF multiplexer, and power supply nearby the tank

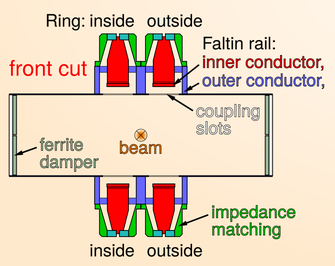
noise figure (typ. LNA):



- remote controlled RF multiplexer to select measurement signal from the main control room
- LNA inputs instead of normal terminators
- without the subsequent signal processing
- stored proton beam, weakly bunched (for BPM)
  - · normal velocity factor: β = 0,830
  - · typical number of protons: N = 1.7·10^{10} (measured for each run)
  - · typical beam dimensions: Δx = 5.3 mm, Δy = 3.9 mm
  - · dispersion at Palmer-PU: D = 0m
  - · RMS momentum spread: Δp/p = 2.2·10^{-4}

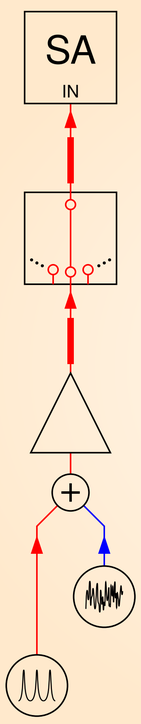
Palmer Pick-up for the Collector Ring (CR) of FAIR



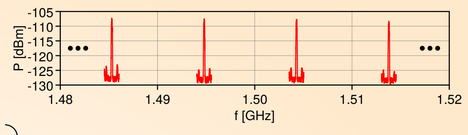


- Palmer pick-up with high acceptance for stochastic pre-cooling of very hot rare isotope beams
- small distance to the kicker for low undesired mixing
- uses Faltin type structures for coupling
  - · mechanically simple but show an high dispersion
    - → 4 long rails of the Palmer arrangement divided into upstream and identical downstream parts
    - → octave bandwidth
- ferrite material for damping of undesired modes (116· Ferroxcube 4S60 64·64·6 mm³)
- developed using HFSS FEM field calculation program
- tested with beam in the **Co**oler **Sy**nchrotron (COSY) of the **F**orschungs**z**entrum **J**ülich (FZJ)

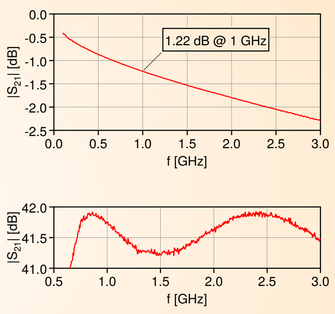
Measurement and Data Analysis



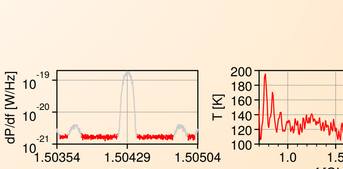
- 220 spectrum sweeps per output and beam position recorded
  - · center frequencies in the range 0.3…2.3 GHz, at harmonics of revolution frequency
  - · sweep span: 1.5 MHz points: 1001
  - · resolution bandwidth: 10 Hz video bandwidth: 20 Hz
  - · detector: RMS



- transmission line from RF multiplexer to spectrum analyzer
  - · 50 cm Semi-Flex .141
  - · attenuation curve from data sheet
- RF multiplexer 8:1
  - · remote controlled device from HESR cooling system
  - · attenuation of multiplexer together with both transmission lines measured at 1 GHz using a power meter Rohde & Schwarz NRX with test generator option NRX-B1 and power sensor NRP18S.
- transmission line from amplifier to RF multiplexer
  - · 3 m flexible Suhner SX04272D-02
  - · measured attenuation curve



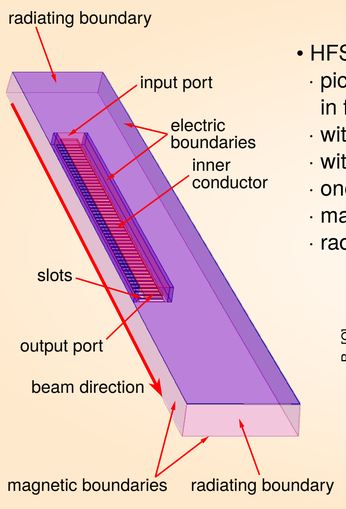
- low noise amplifier (LNA)
  - · Miteq AFS3-01000200-07-10P-GW-APM
  - · measured gain curve for each individual device



- calculate spectral power density
  - · consider attenuation of transmission line, RF multiplexer
  - · consider gain of amplifier
  - · filter response of spectrum analyzer checked by test generator
- noise
  - · for each spectrum sweeps: calculate mean spectral power density without main and side peaks of Schottky signal
  - · calculated noise temperature is the temperature of a normal resistive terminator at the input of a noise free amplifier
    - → noise of the LNA is included in the calculated noise temperature
- Schottky signal
  - · mean noise is subtracted
  - · line power (P_{line}): integral over peaks of Schottky signal
  - · shunt impedance (in circuit convention) for N protons (q_e):

$$R_{||} = \frac{P_{line}}{2 \cdot N \cdot (q_e \cdot f_{rev})^2}$$

Electrodynamic FEM Calculation



- HFSS (High Frequency Structure Simulator)
  - · pick-up simulated as kicker in frequency domain
  - · without matching cones
  - · without ferrite
  - · one quarter simulated
  - · magnetic boundaries at symmetry planes
  - · radiating boundaries at ends of beam pipe

- MWS (MicroWave Studio)
  - · pick-up simulated as kicker in time domain + FFT
  - · with matching cones
  - · without ferrite
  - · full geometry simulated
  - · no symmetry planes
  - · ports at ends of beam pipe

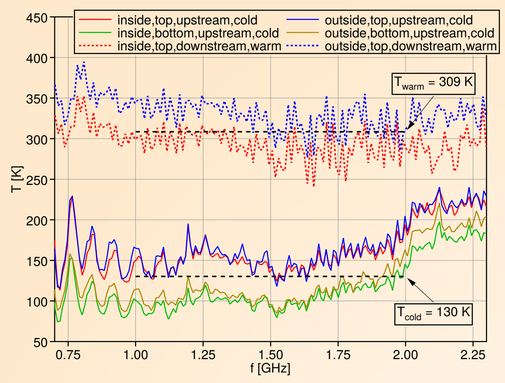
Conclusion

- The Palmer pick-up for the **C**ollector **R**ing (CR) of the future FAIR facility has been tested successfully in the **Co**oler **Sy**nchrotron (COSY) at the **F**orschungs**z**entrum **J**ülich (FZJ).
- The presented measurement results show a good agreement with electromagnetic FEM simulations (HFSS and Microwave Studio).
- The LNAs instead of resistors as artificial cold loads works as expected. We have achieved a mean noise temperature of 130 K in the frequency rage 1…2 GHz at room temperature.

Acknowledgement

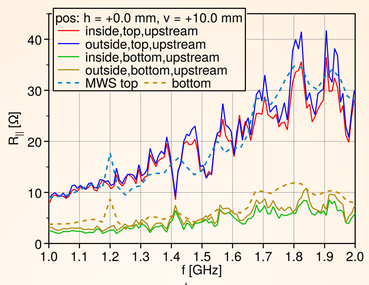
- The authors thank the COSY team for the good prepared and smooth-running beam time, and especially Nikolay Shurkhno for his very helpful and agile data acquisition software.

Results



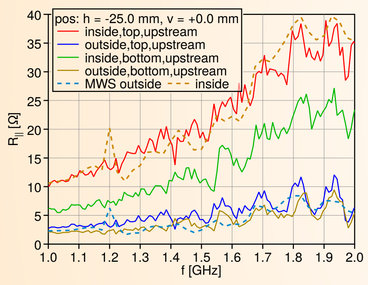
- test efficiency of the active artificial cold terminators
  - · installed LNAs as cold loads at the inputs of four upstream Faltin rails
  - · normal passive terminators at the two downstream rails at the top side
  - · two downstream rails at the bottom side not measured (probably contact problems)
- artificial cold rails
  - · mean noise temperature 130 K at 1…2 GHz
  - · achieved at room temperature without any active cooled components
  - · contribution of the LNAs at inputs and outputs ≈56…94 K
  - · remaining noise: losses of Faltin rails, matching, feedthroughs
- normally terminated rails
  - · as expected: noise temperature above room temperature

- verify shunt impedances found by electrodynamic FEM calculations
  - · all values are longitudinal pick-up shunt impedances in circuit convention
  - · signals from single rails
    - → shunt impedance of whole tank in longitudinal mode is 8 times this values (4 rails · 2 sections)
    - → no values for Palmer mode

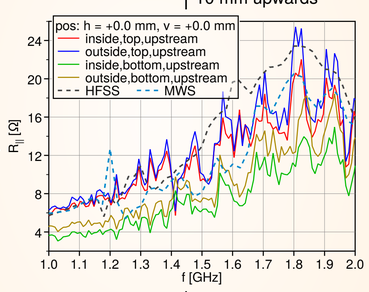


- beam positions
  - · position values from COSY BPMs
  - · position in respect to the mechanical center of structure
  - · no electrical adjustment done
  - · measurements with beam on axis
  - · … with horizontal offset ±25 mm
  - · … with vertical offset ±10 mm

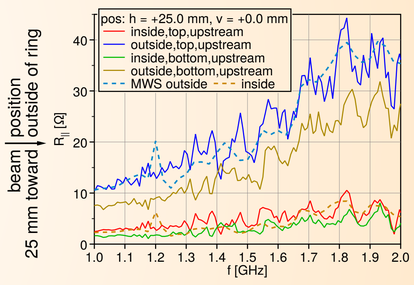
beam position 10 mm upwards



beam toward 25 mm position inside of ring

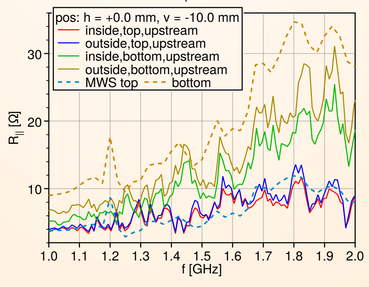


beam toward 25 mm position outside of ring

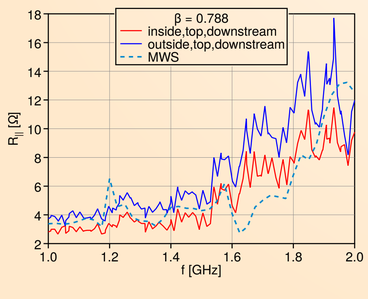


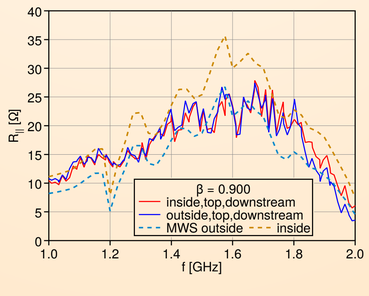
beam position 10 mm downwards

- comparison with FEM calculations
  - ◦ HFSS calculation
    - · only for beam on axis (one quarter simulated)
    - · only for β = 0.83
  - ◦ MWS calculations
    - · also for other beam positions (full geometry)
    - · also for different β



- results
  - ◦ beam on axis
    - · good agreement with MWS
    - · reasonable agreement with HFSS
    - · beam not exactly on electrical axis
  - ◦ beam off axis
    - · behave as expected
    - · good agreement with MWS
    - · mechanic and electrical axis slightly deviant
  - ◦ FEM calculations
    - · results are reliable





- β variation
  - · check usability for slightly different β
  - ◦ β = 0.788
    - · only one MWS curve: h = ±1 mm is inside the same mesh cell
    - · good agreement with MWS
  - ◦ β = 0.900
    - · good agreement with MWS
  - · from the point of mag($R_{||}$), the PU is still usable
  - · phase can not be measured