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TIME DOMAIN CHARACERIZATION OF HIGH POWER RF PULSED SOLID STATE AMPLIFIERS FOR LINEAR ACCELERATORS

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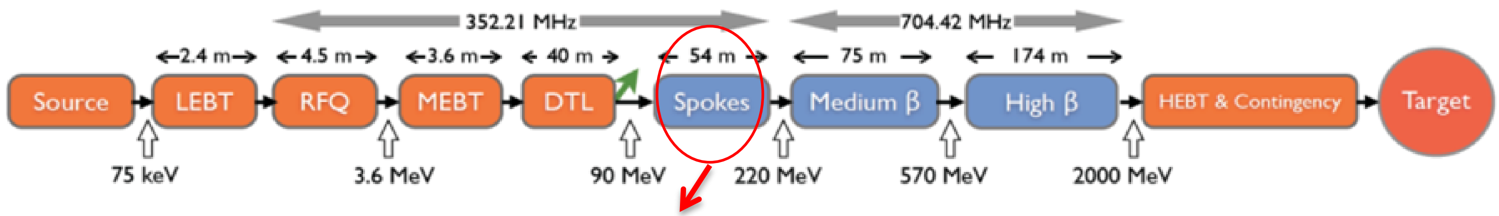
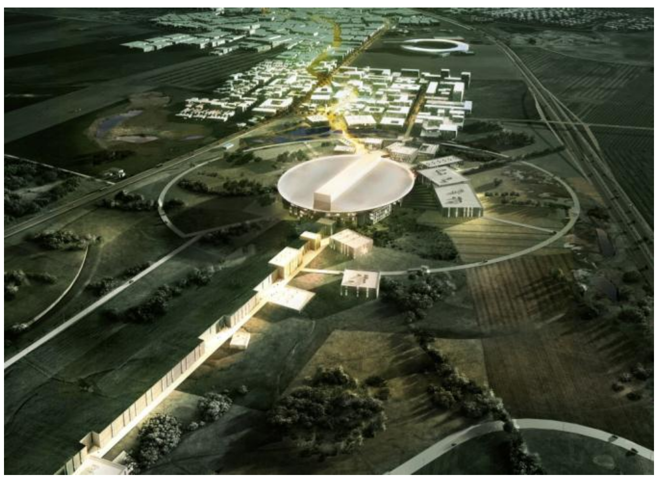
RF Development at FREIA

Facility for Research Instrumentation and Accelerator Development

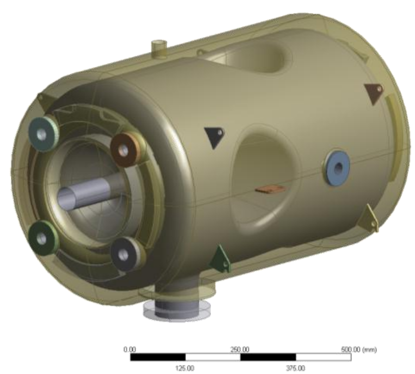
Schematic of ESS Linac



Superconducting Spoke Linac



ESS construction in Lund



SRF Cavity
(Superconducting)

Specifications for Spoke amplifier:

- Frequency = 352 MHz
- Power = 400 kW
- 3dB band-width ≥ 250 kHz
- Pulse width = 3.5 ms
- Pulse repetition rate = 14 Hz

FREIA's responsibilities:

- Developing RF test stand for ESS spoke cavities.
- Testing prototype spoke cavities.

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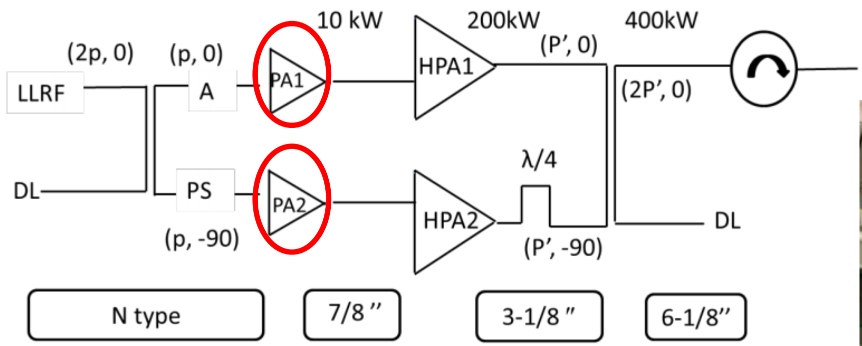
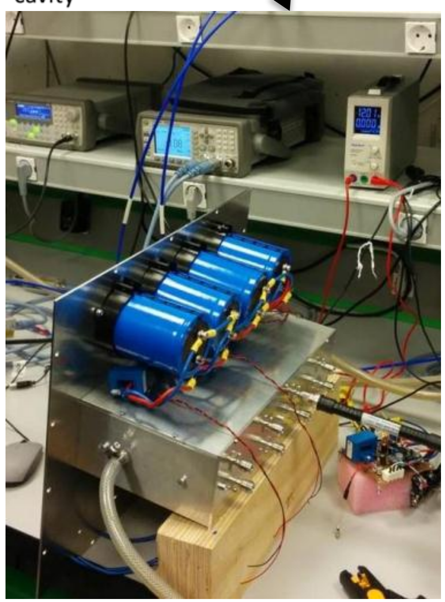
The Tetrode-based Power Station

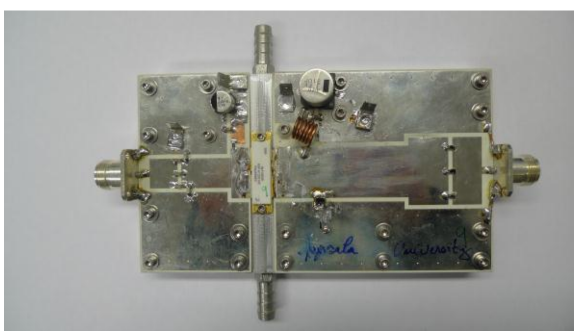
Tetrode-based

- Based on 2xTH-595, water+air cooled
- Solid-state pre-amplifier

See talk:
Preliminary measurements of eight solid-state modules of the 10 kW pulsed power amplifier at 352 MHz under development at FREIA







In-house development:

- Optimizing 1 kW transistor modules
- Power combining methods
- 10 kW prototype amplifier

Why do we need time domain measurements

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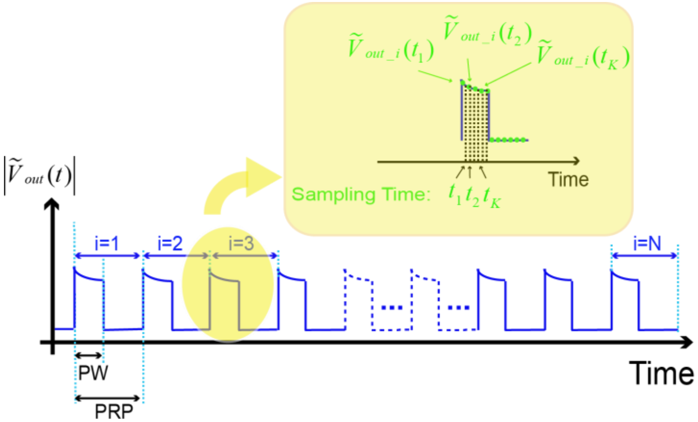
- To validate the optimized SSPA module, it's critically important to characterize every single modules.
- Time domain measurements for characterization
  - ✓ Drain Current/Drain Voltage
  - ✓ Temperature
  - ✓ Pulse profile measurements
  - ✓ Evaluating the efficiency of the SSPA

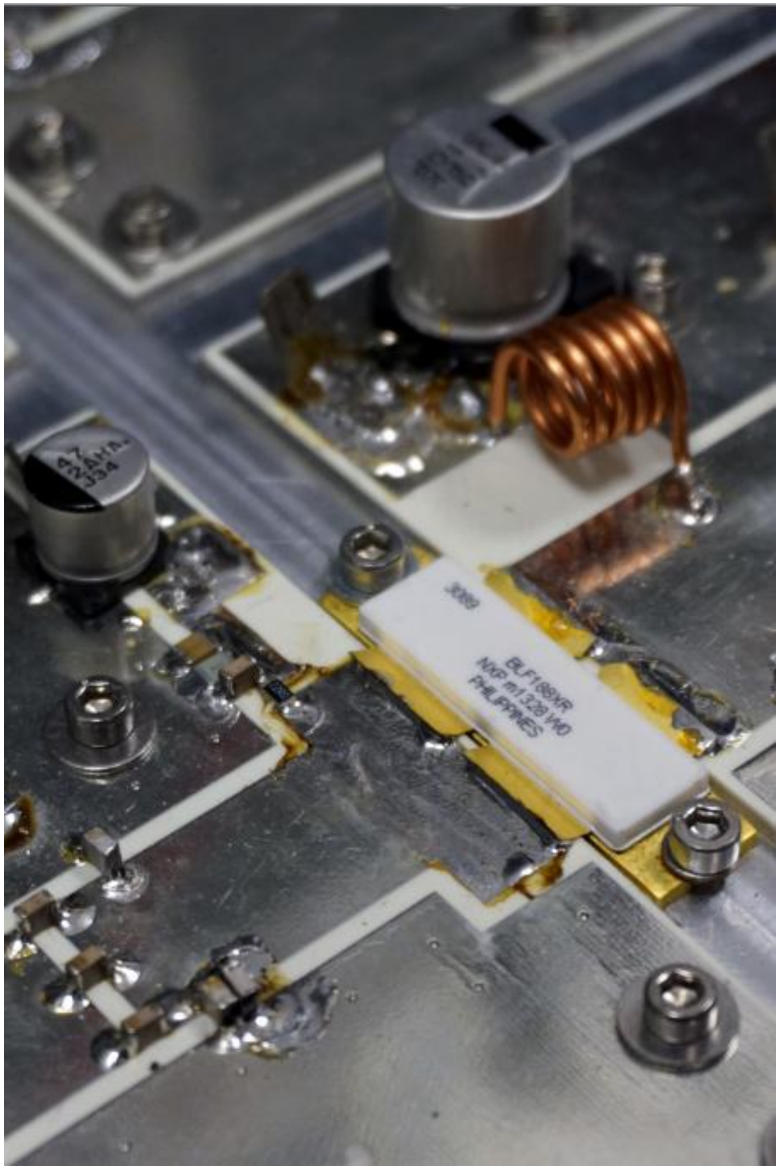
$$\eta_{Drain} = \frac{P_{RFOUT}}{V_{DRAIN} x I_{DRAIN}}$$

  - ✓ Pulse to pulse amplitude and phase stability.

$$\overline{Stability(t_k)} = 10 \times \log\left[\frac{1}{N}\sum_{i=1}^{N}\left(\widetilde{V}_{out\_i}(t_k) - \widetilde{V}_{out}(t_k)\right)^2\right]$$

$$\widetilde{V}_{out}(t_k) = \frac{1}{N}\sum_{i=1}^{N}\widetilde{V}_{out\_i}(t_k)$$





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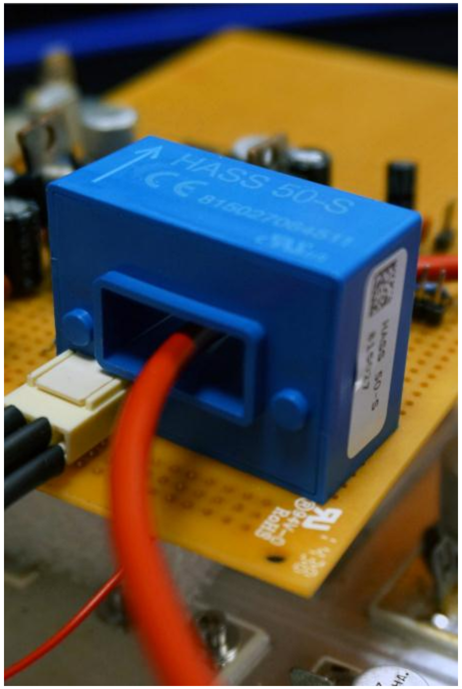
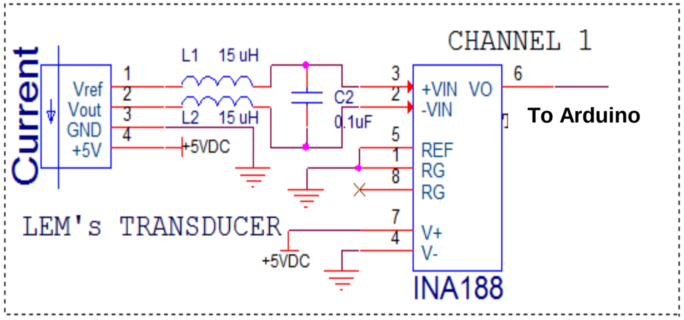
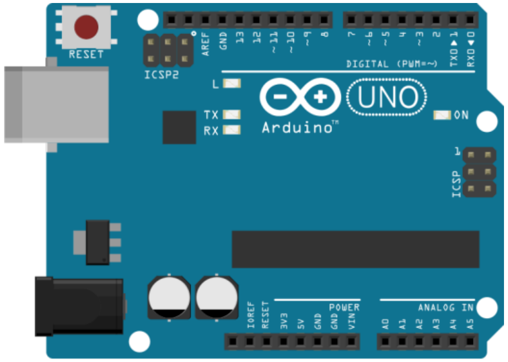
Solutions for The Monitoring Circuit



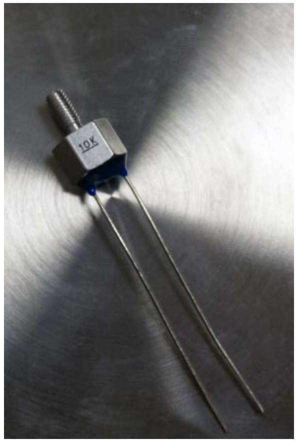
- LEM's transducer HASS 50-S
    - Hall effect principle
    - Fixed offset and gain
    - Small size, low cost, easy to install
    - Immunity to interference
    - 1% accuracy
- Good solution to replace the Fluke's probe



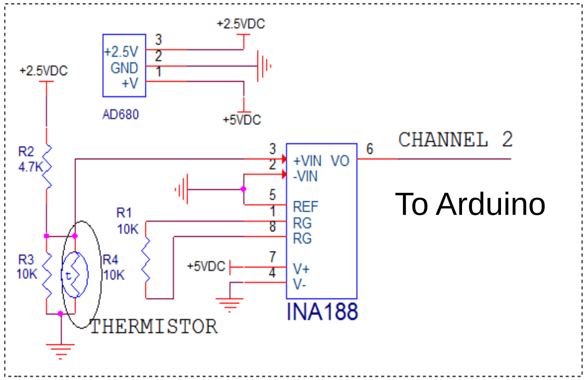
Current Measurement Module



Arduino as a Processing Unit

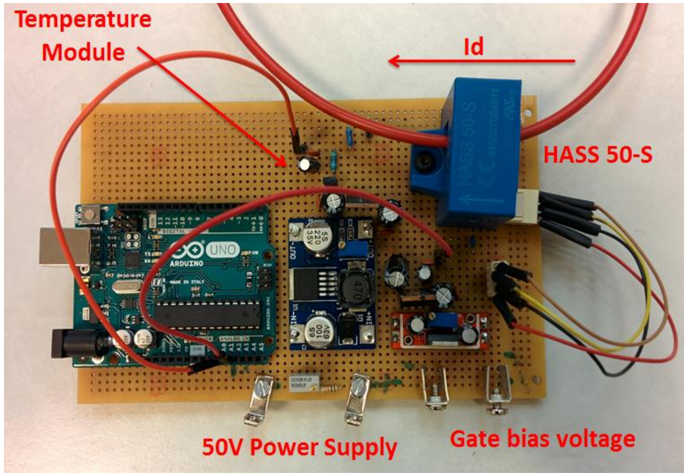


- NTC Thermistor
- Low cost
- High sensitivity to Temp
- Non-linear Characteristic
- Calibration Requirement

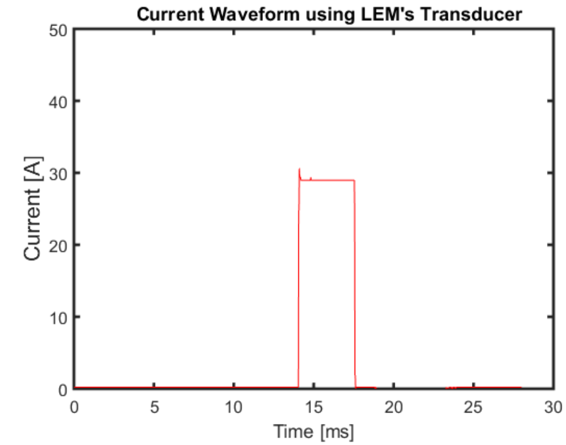


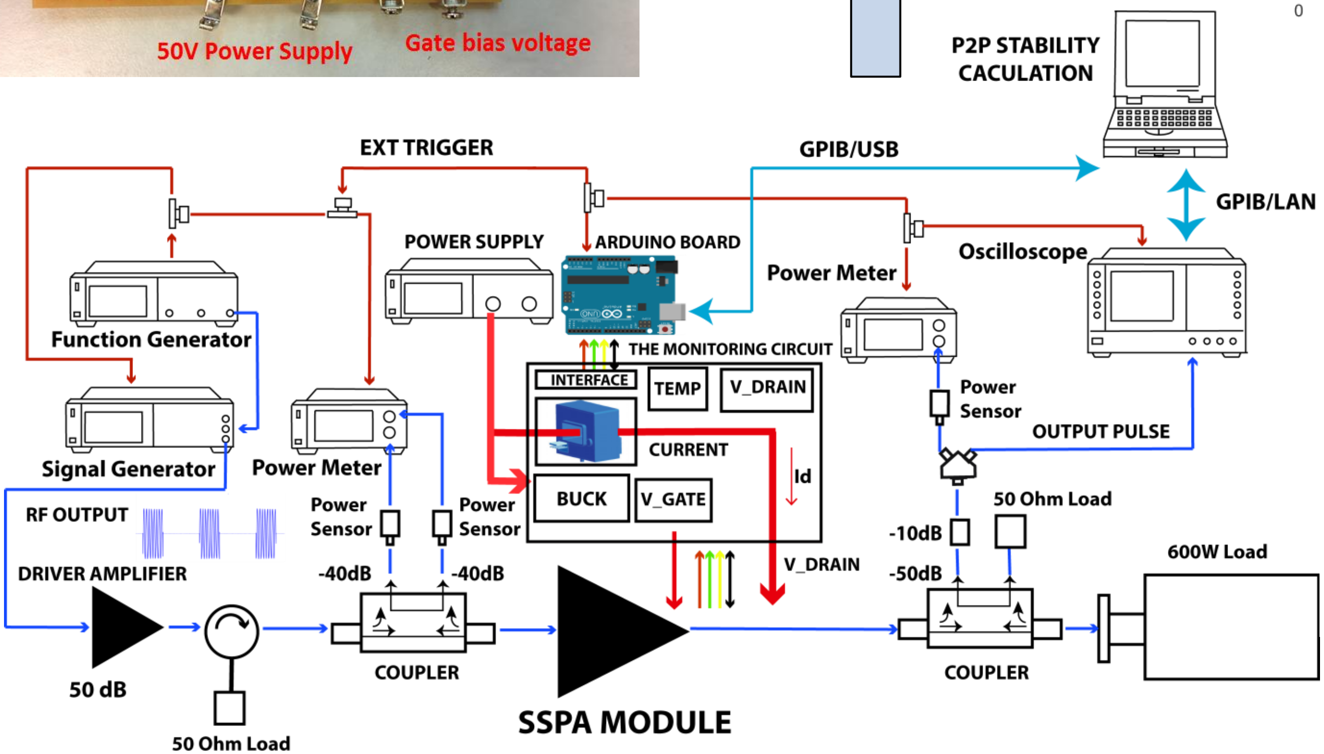
Temperature Measurement Module

The Time Domain Characterization Setup

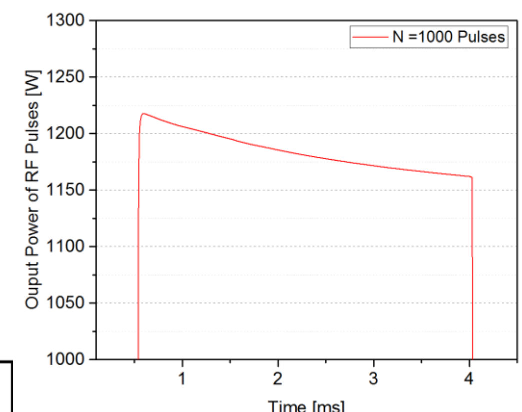


Pulsed current output

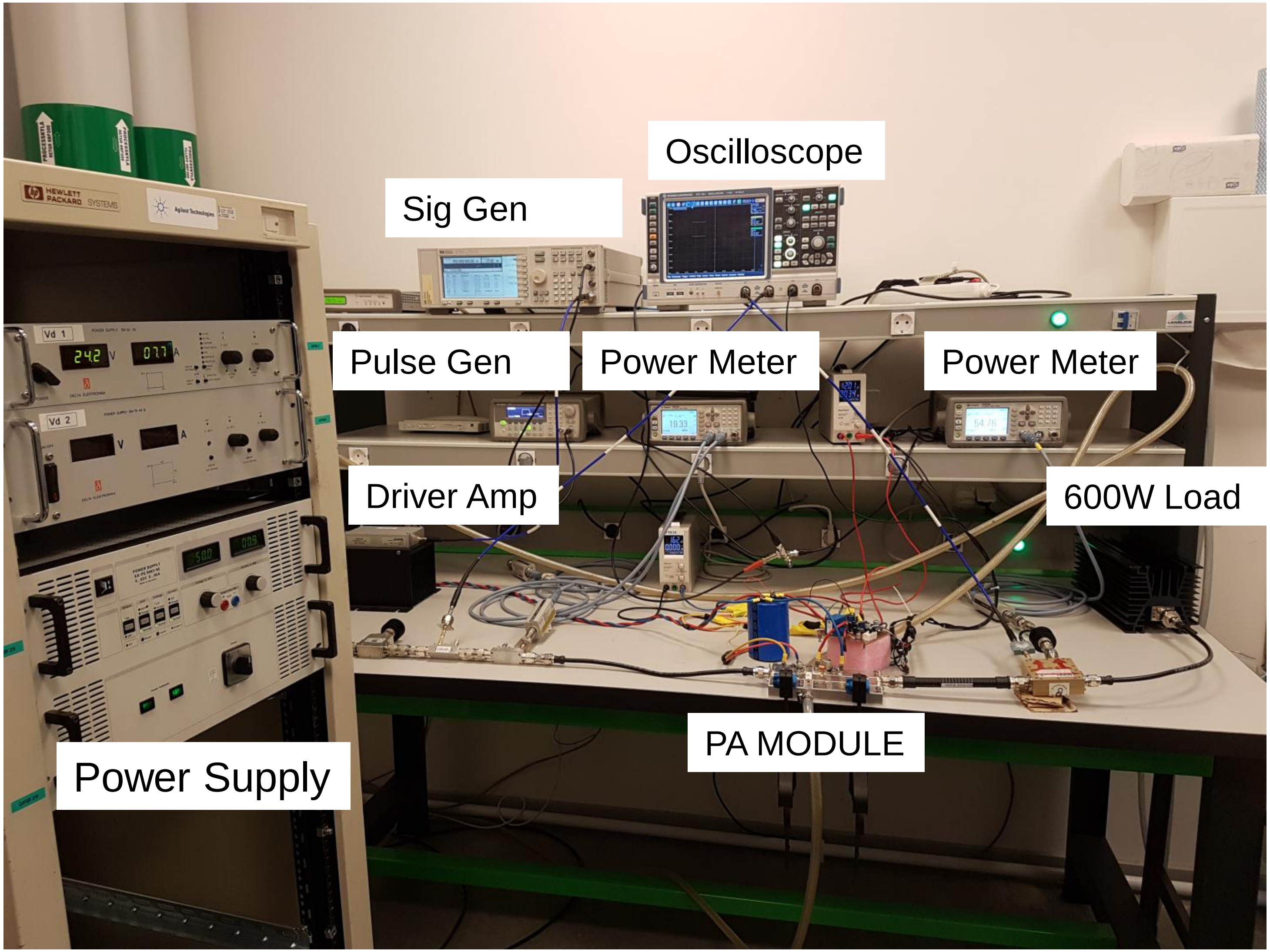




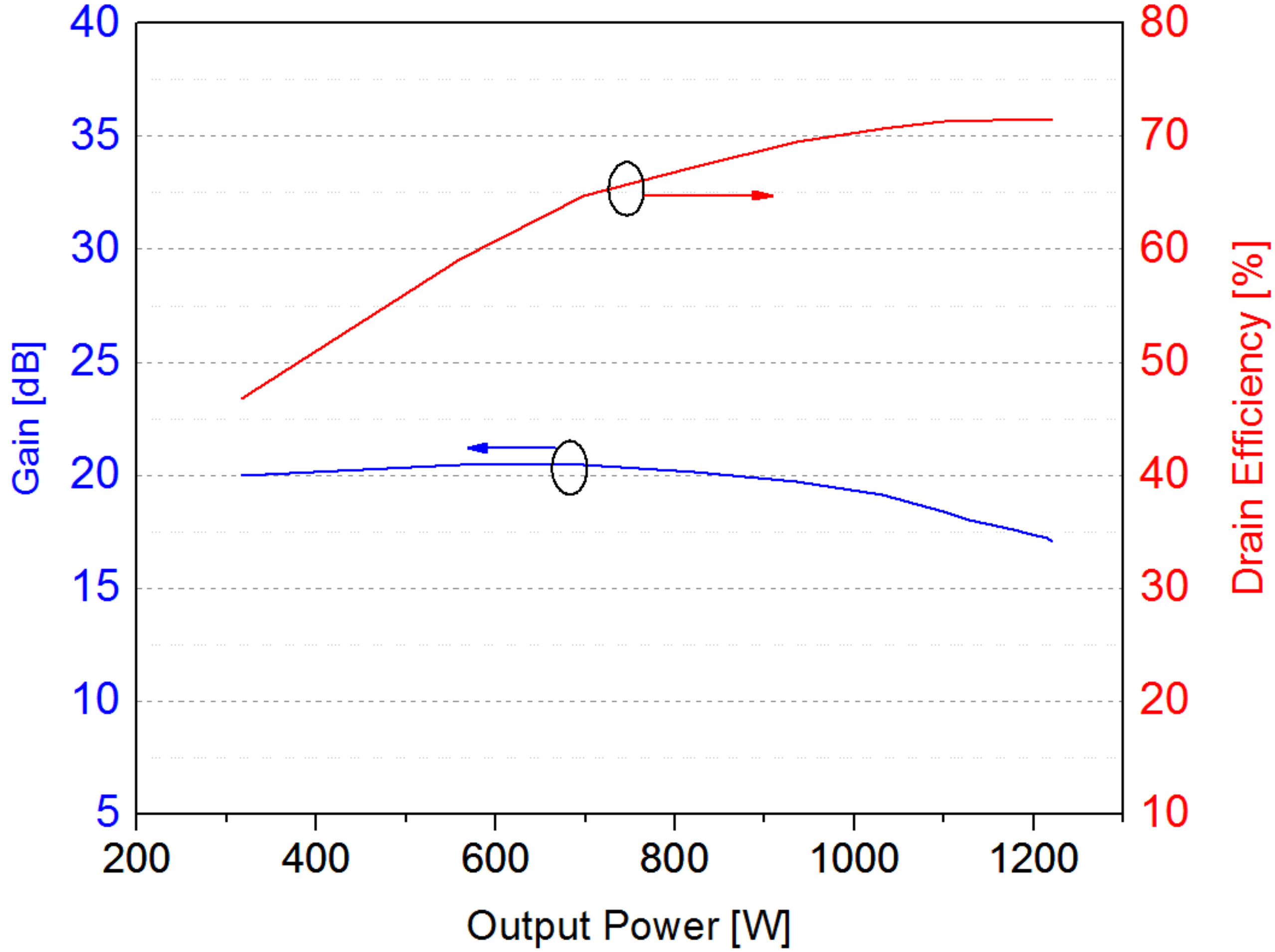
Envelope Pulse



The Realized Measurement Setup



Efficiency is 70% at 1.2 kW output power



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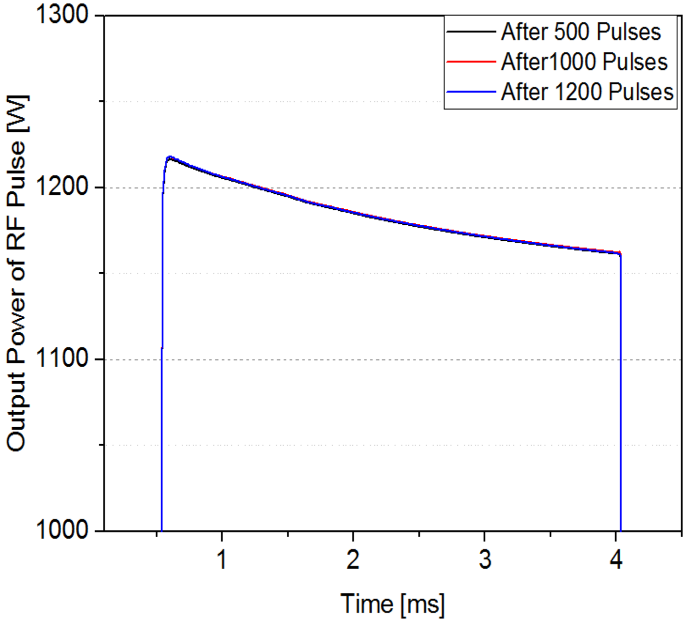
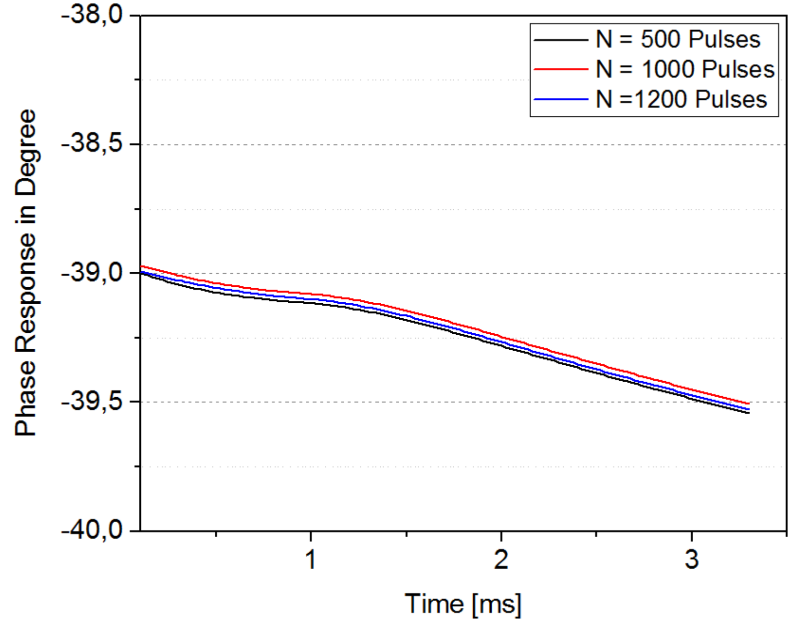
Pulse Profile at 1.2 kW output

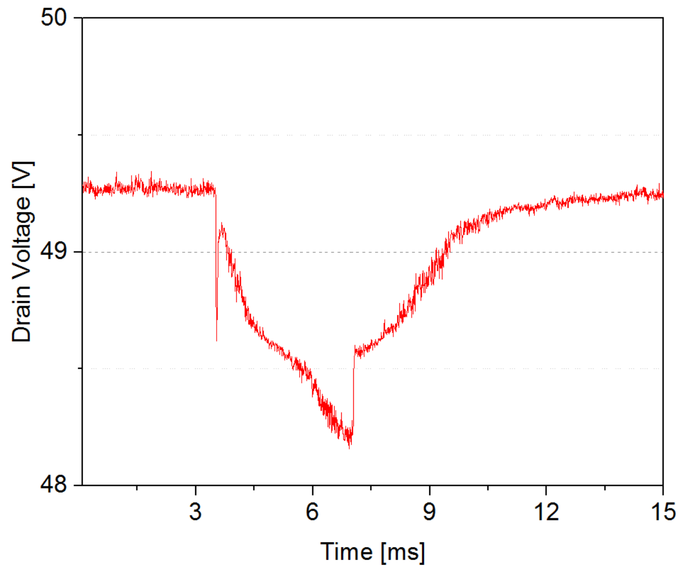


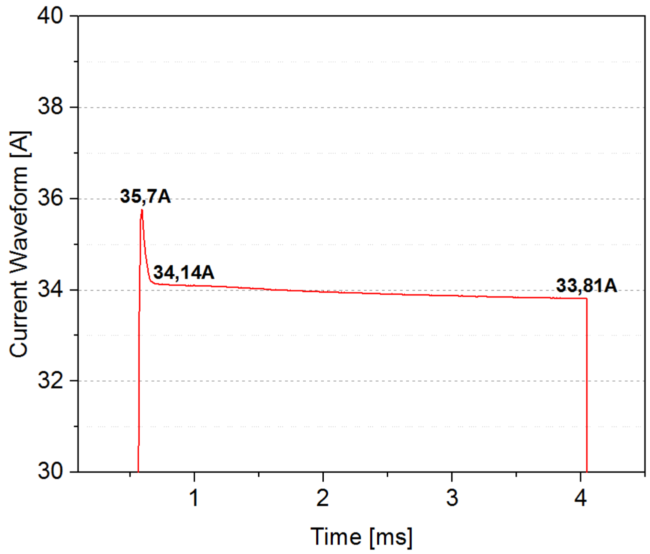


0.2 dB Droop in RF waveform

Insertion phase is measured -39

Drain Voltage and Current Measurements



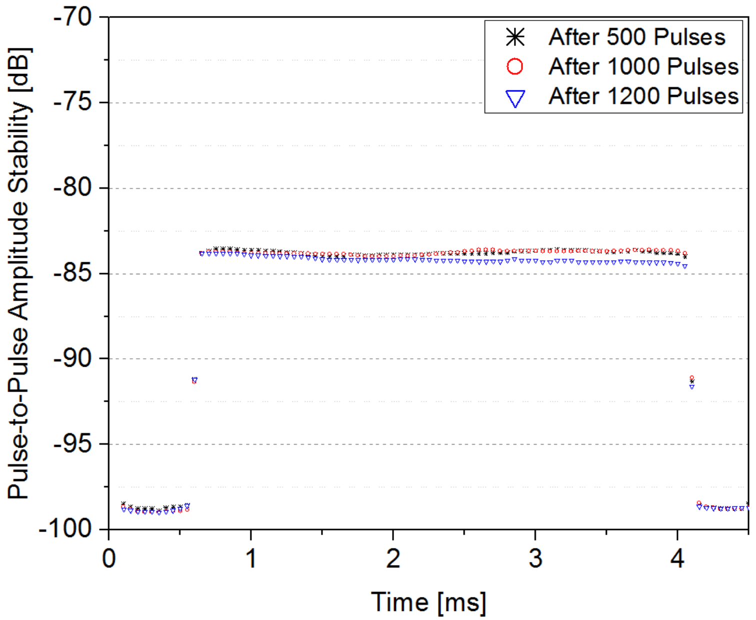


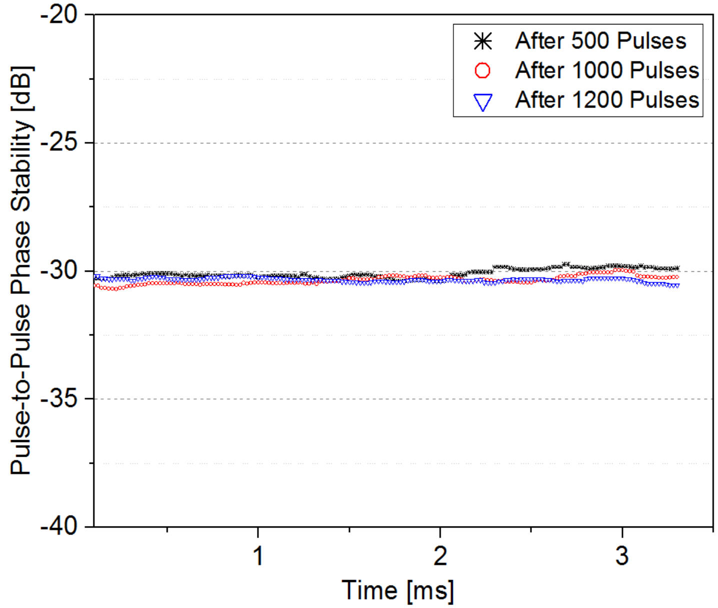
Droop around 1V at 1.2 kW

5% overshoot in current waveform

- The efficiency is around 70% and drops 2% along the pulse

Stability Performance at 1.2 kW output





-85 dB amplitude stability

-30 dB phase stability

CONCLUSION

- A measurement setup is presented for time domain characterizing solid state high powers to be used in particle accelerators.
- A standard deviation of -85 dB in amplitude and -30 dB in phase is obtained to demonstrate the stability performance of the tested PA.

THANK YOU FOR YOUR ATTENTION