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Investigation of an emission current regulation circuit in the frequency domain

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- Measurement setup and characterization
- Intentional noise modulation onto the emission current
- Noise behaviour of the samples using the current regulation circuit
- Conclusion

Motivation

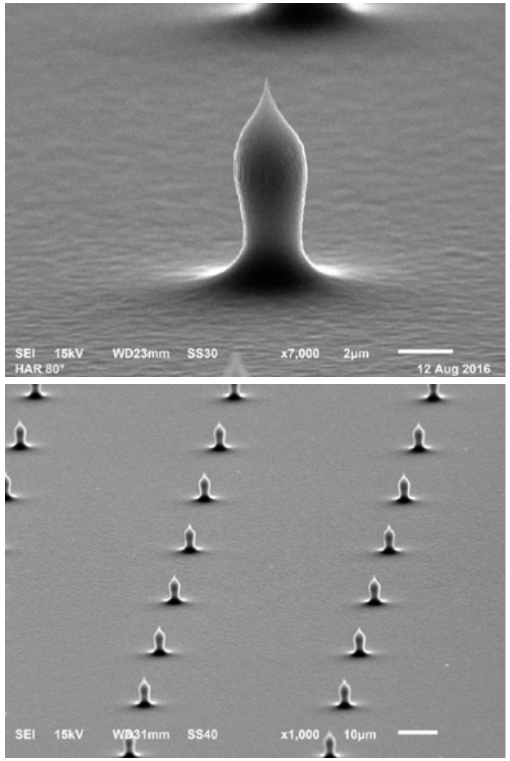
- Effective electron sources compared to other electron sources (tubes → heat losses)
- No thermal processes → Fast switching
- Used by different devices
  - X-Ray sources
  - Vacuum gauges
  - Electron guns
  - …

- Problem: Stability and electron yield depends on doping
  - Metal-like emitters results in higher current values but lower stability
  - P-type emitters have high stability but lower current values

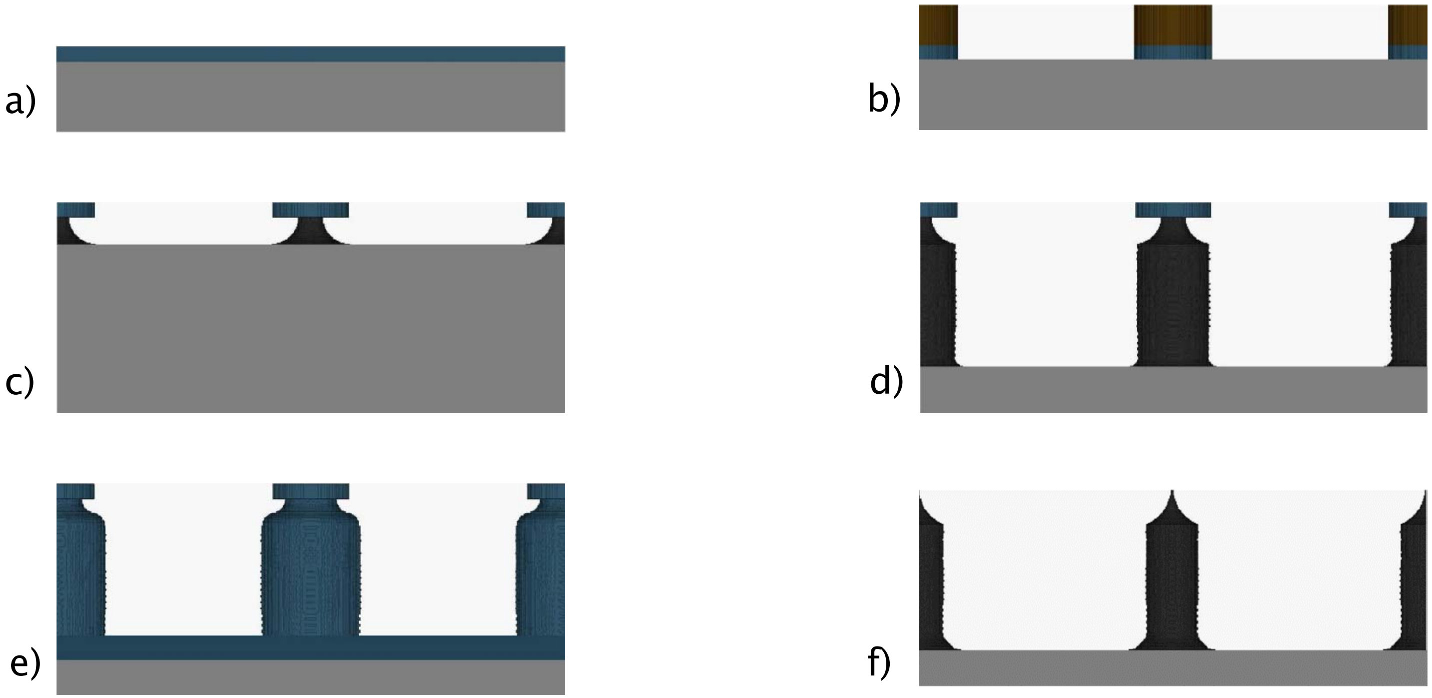
➢ Use of a current regulation circuit
  - ➢ Setting a desired target emission current
  - ➢ Suppress noisy frequencies of the emission current
  - ➢ Use frequency domain to check the regulation circuit performance

Investigated micro-structures

sample	**A**	**B**
substrate	p-type Si	undoped Si
dopant concentration	10^{15}-10^{16}cm^{-3}	10^{12}-10^{13}cm^{-3}
specific resistivity	1-10Ωcm	1-10kΩcm
coating	none	Au 10nm
total height H	8µm	8µm
pillar diameter $Ø_p$	2µm	2µm
apex radii R	<20nm	<30nm
array size	10 x 10	10 x 10
pitch	50µm	50µm
work function	4.9eV	5.1eV (Au)



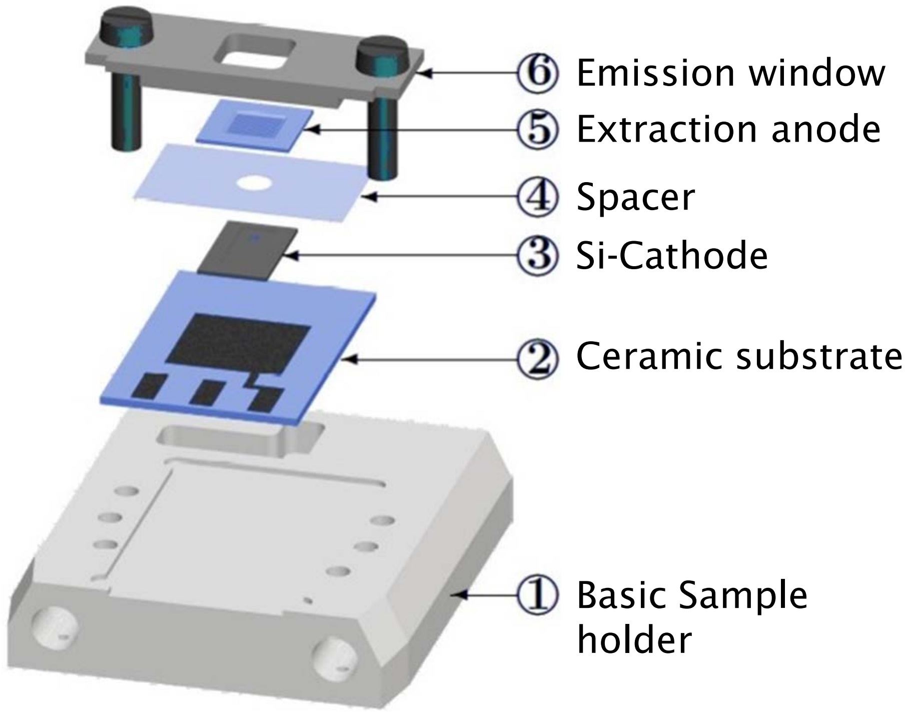
Investigated micro-structures - Fabrication process[1]

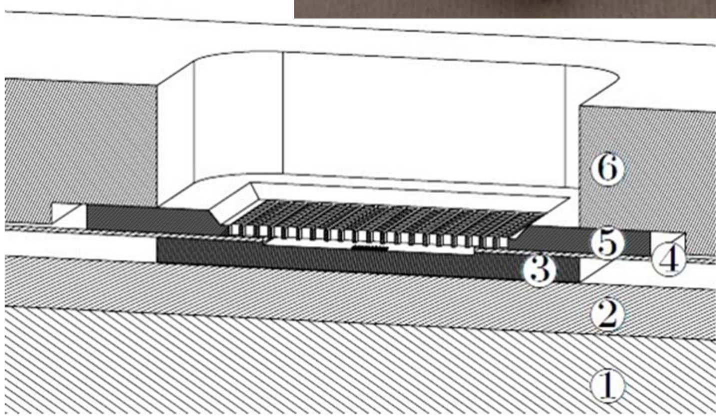


[1] R. Lawrowski, C. Langer, C. Prommesberger, F. Dams, M. Bachmann, and R. Schreiner, “Fabrication and simulation of silicon structures with high aspect ratio for field emission devices,” 2014, pp. 193–194.

Measurement setup

Sample holder





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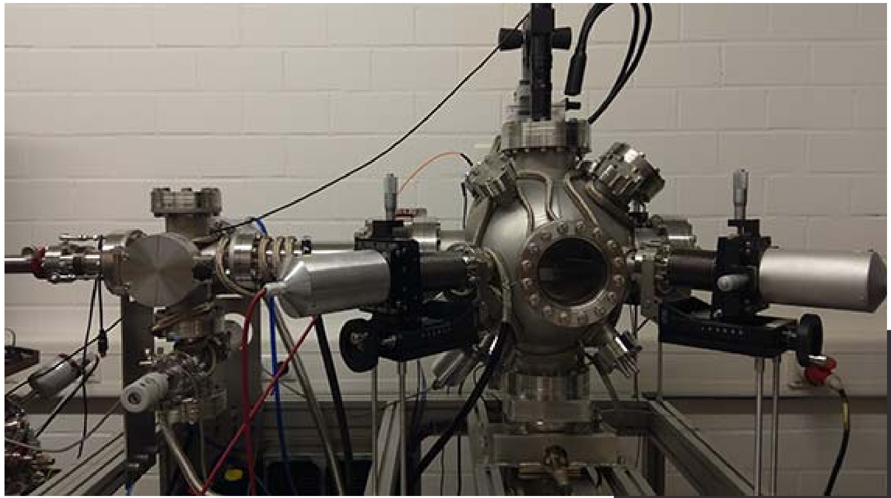
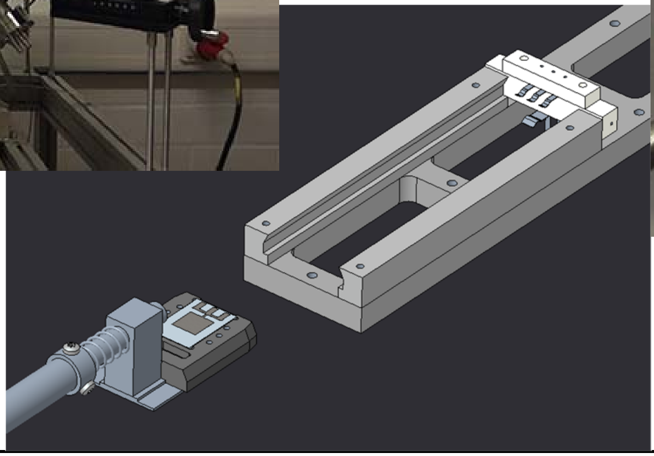
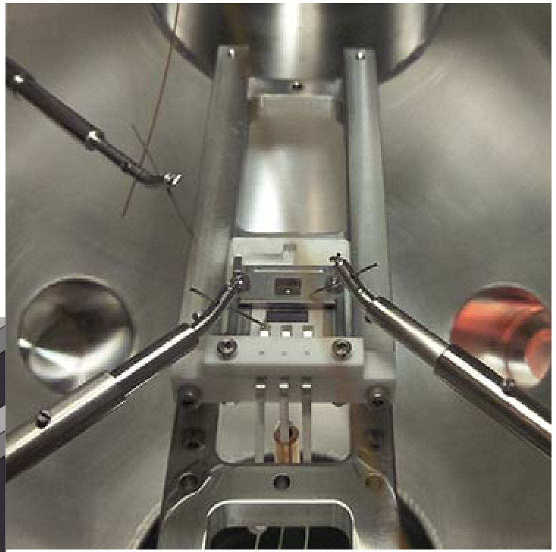
Measurement setup

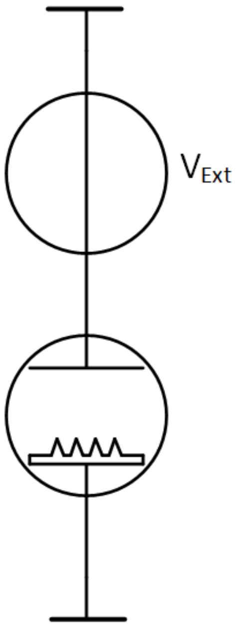
Vacuum chamber and installation



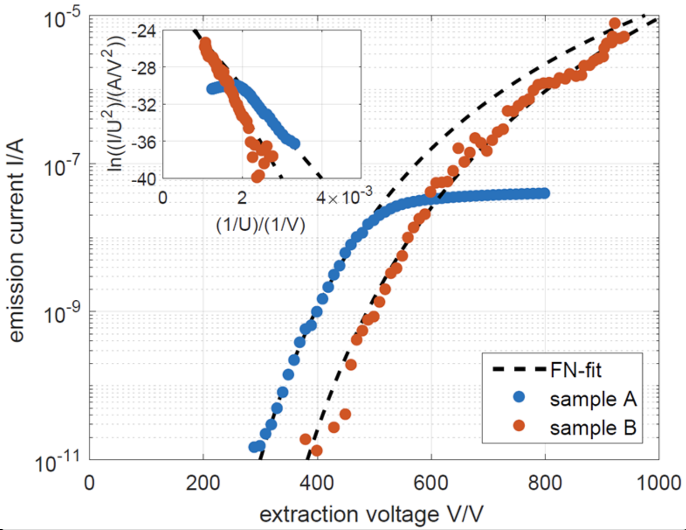




Characterization



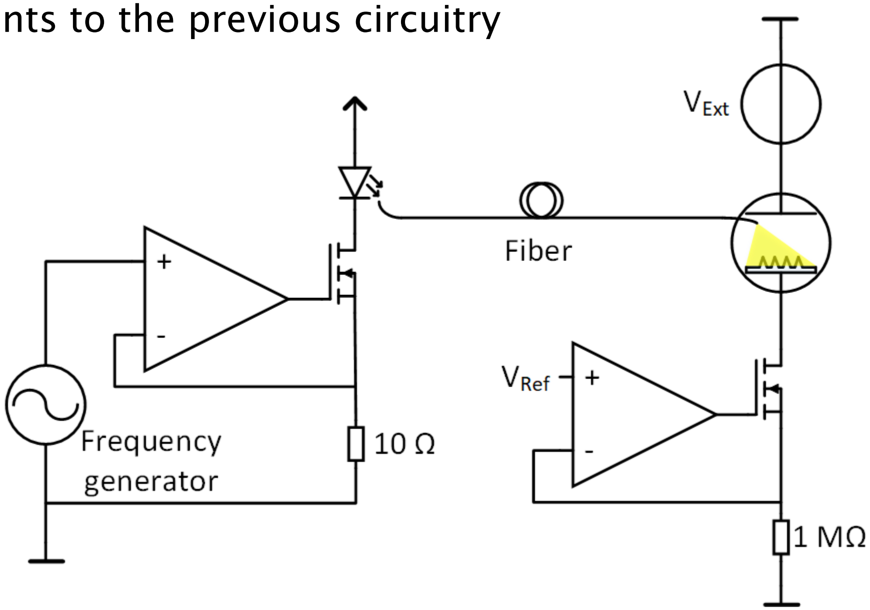
sample	A	B
onset Voltage (1nA)	≈400V	≈490V
max. emission current	39nA	4.1µA
field enhancement factor β	≈750	≈540
emission behaviour	saturation	metal-like



Intentional noise modulation

Emulate an unstable emission behaviour – Extended circuit

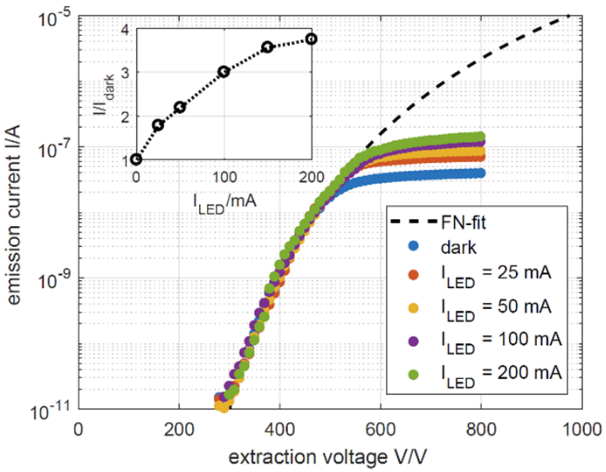
- Exploiting the lightning effect of p-type silicon emitters
- Additional elements to the previous circuitry

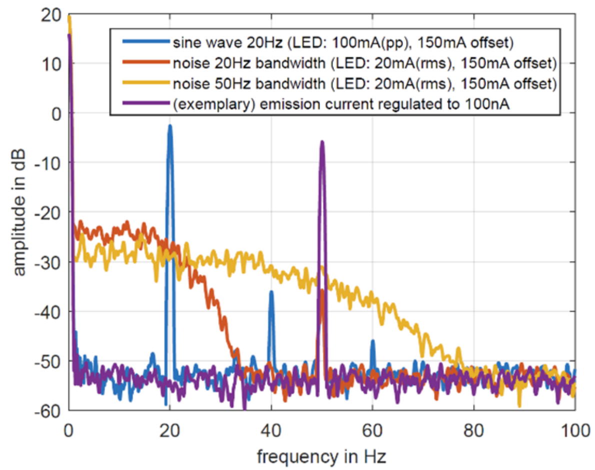


Intentional noise modulation

Emulate an unstable emission behaviour on p-type emitters (sample A)

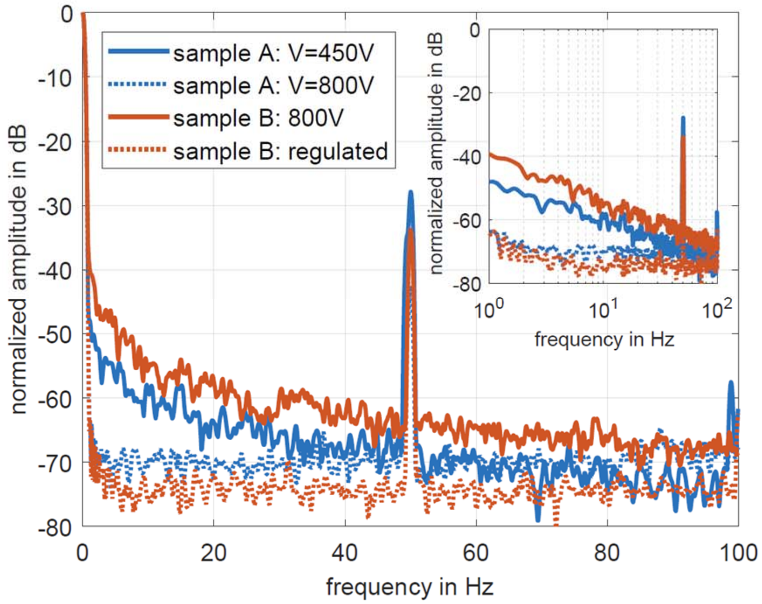
- Current shift up to higher currents due to brighter illumination
- Modulation of sample-signals and –noise to the emission current
- Suppression of the noise by using the regulation circuit





Noise behaviour

Stability of the emission current under real conditions

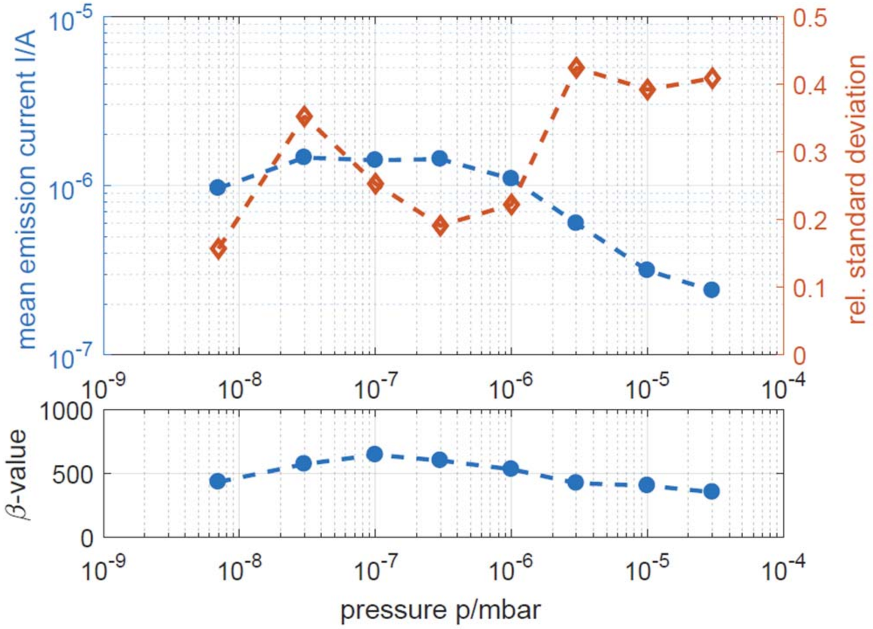


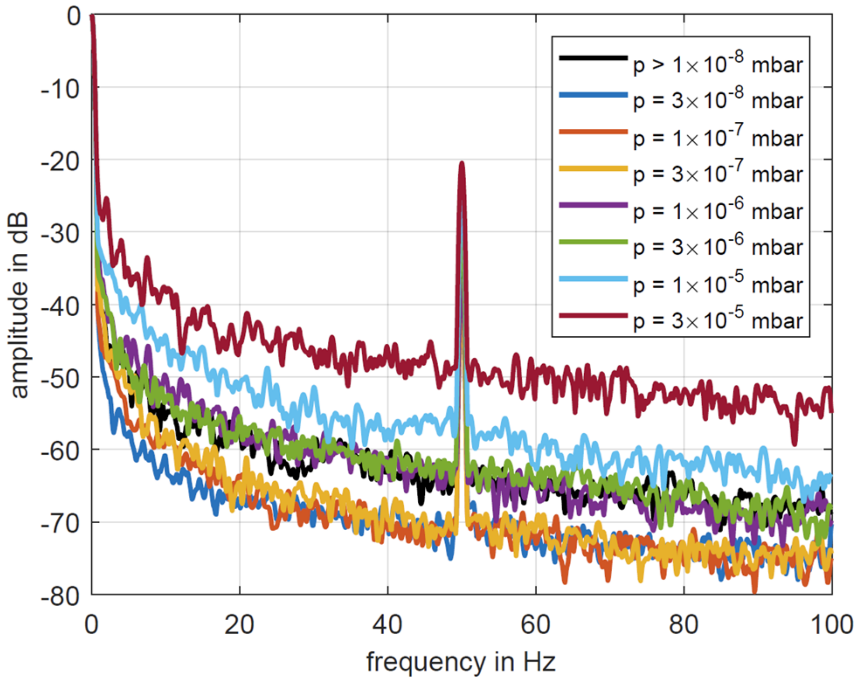
sample A	**below saturation**	**in saturation**
extraction voltage	450 V	800 V
emission current	5.6 nA	39 nA
rel. standard deviation	±16 %	± 0.3 %

sample B	**no regulation**	**regulated**
extraction voltage	800 V	N/A
emission current	0.96 µA	1 µA
rel. standard deviation	±16 %	± 0.4 %

Noise behaviour

Pressure influence – short term measurements





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Conclusion

1. Our conventional field emission setup is extended due to noise emulation exploiting p-type lightning effects by a:
   - current regulation circuit
   - supply circuit for noise emulation LED
2. Sample A emission follows the LED-Noise like expected
3. The regulation circuit has an excellent regulation behaviour
   - Suppression of the field emission noise
   - High stability of emission current
   - Variation of extraction voltage (problematic for applications)
4. Typically pressure dependence is observed like expected
5. Powerline has a non-neglectable impact in our emission current

➢ More compact regulation circuit design and improved shielding for the entire measurement setup

➢ Measurement of pressure dependence using regulation circuit

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