Influence of Pressure on Breakdown Characteristics of Liquid Nitrogen in Non-uniform Electric Fields

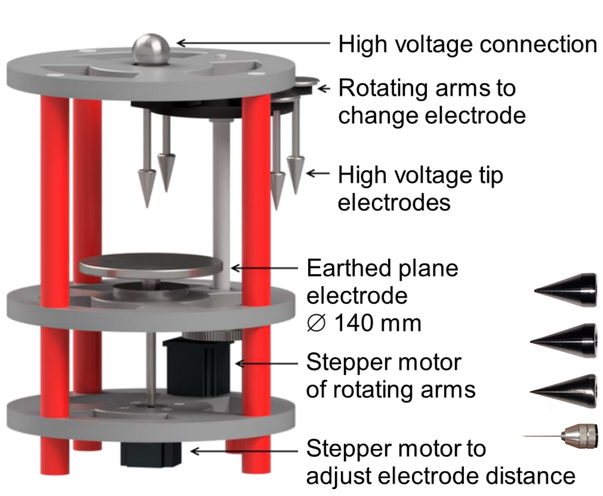
Technology
Arts Sciences
TH Köln

H. Seufert, R. Brüstle, F. Kasten, G. Pfeiffer, R. Schumacher, C. Humpert

Introduction

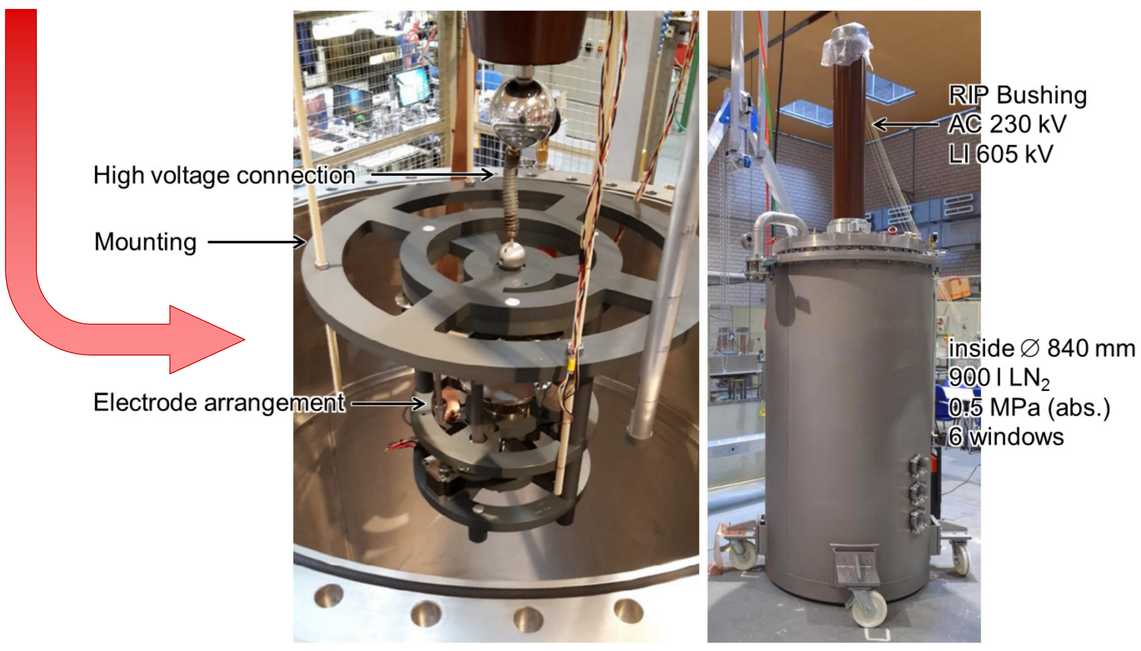
To make superconducting devices more compact or to enhance them for high voltages it is necessary to know the breakdown (BD) characteristics of LN_2 more in detail, especially if sharp edges occurring for example at 2G tapes cannot be avoided.

Experimental Setup



$$\eta = \frac{E_{mean}}{E_{max}}$$

	Tip radius r (mm)	Electrode distance d (mm)	Field utilization factor η	Absolute pressure p (MPa)
	2.0	10 – 50	0.23 – 0.08	0.10 – 0.30
	1.0	10 – 50	0.14 – 0.05	0.10 – 0.40
	0.5	10 – 50	0.09 – 0.03	0.10 – 0.49
	~ 0.1	10 – 50	0.02 – 0.006	0.10



Measurement of AC breakdown (BD) voltage V_{BD} in the cryostat

- Slew rate of applied voltage: 5 kV/s
- 6 measurements for each combination of r, d and p to prevent intense abrasion of high voltage tip electrodes
- Calculation of mean BD strength: $E_{BD} = V_{BD} / d$
- Calculation of maximal BD strength: $E_{BD,\,max} = E_{BD} / \eta$

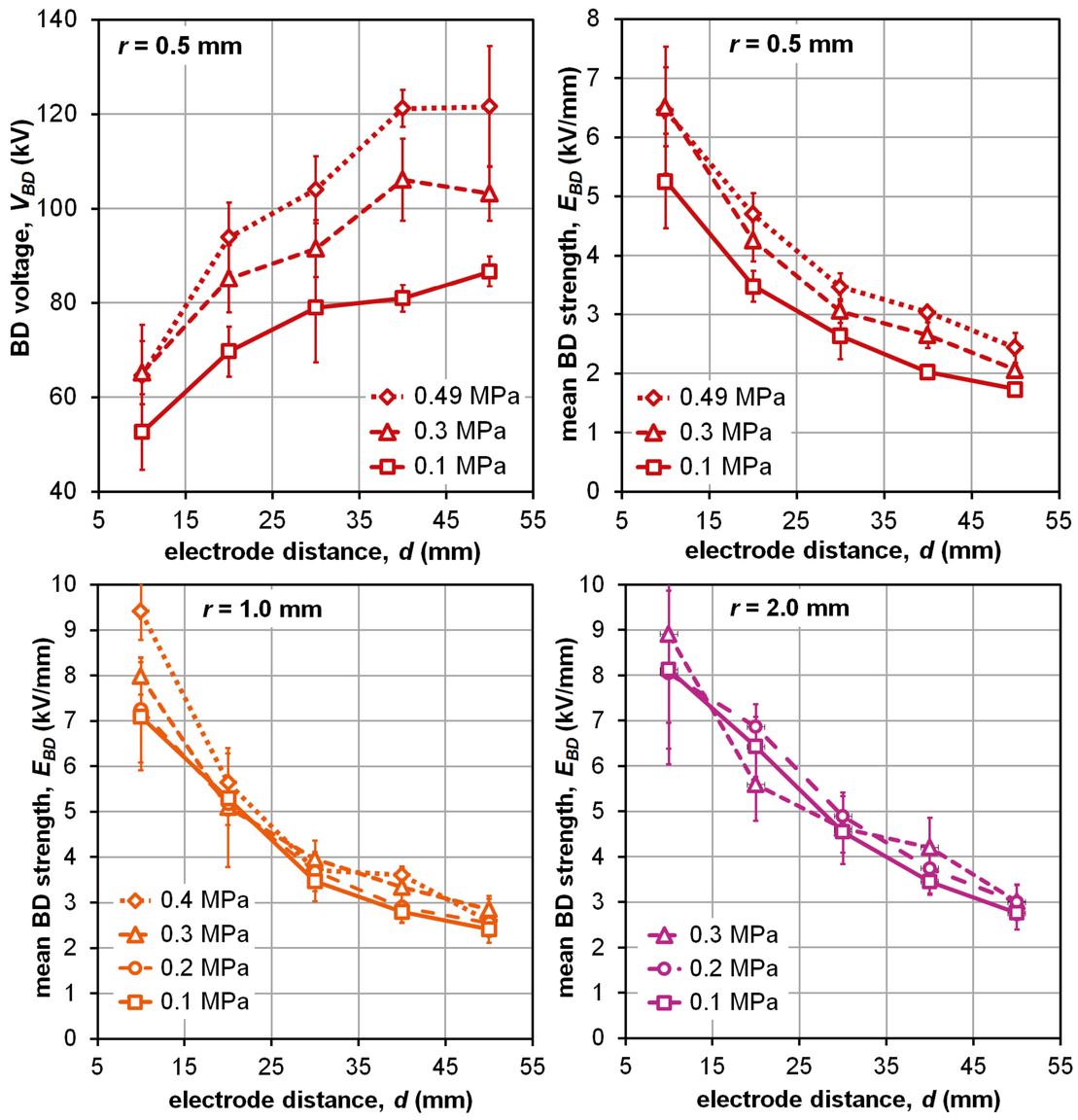
Measurement of AC inception V_{inc} and extinction voltage V_{ext} of partial discharges (PDs) in open box at normal pressure

- Stepwise voltage increase with holding times of 5 min
- Criterion: apparent charge over / under 5 pC for 60 s
- Measurements repeated 10 times for each arrangement

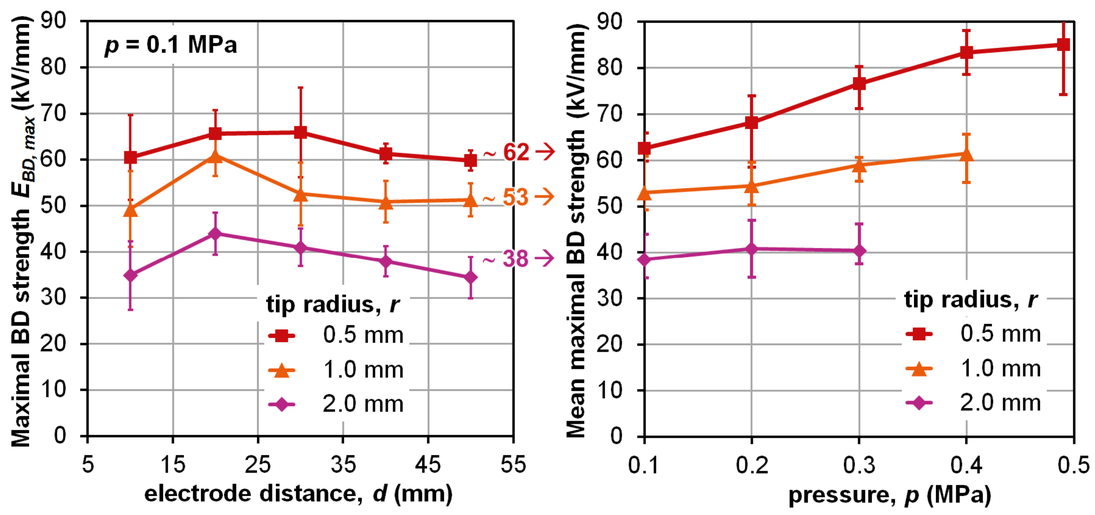
General

- Calculation of arithmetic mean and standard deviation
- All results given as peak value divided by square root of two

Influence of Pressure on Breakdown



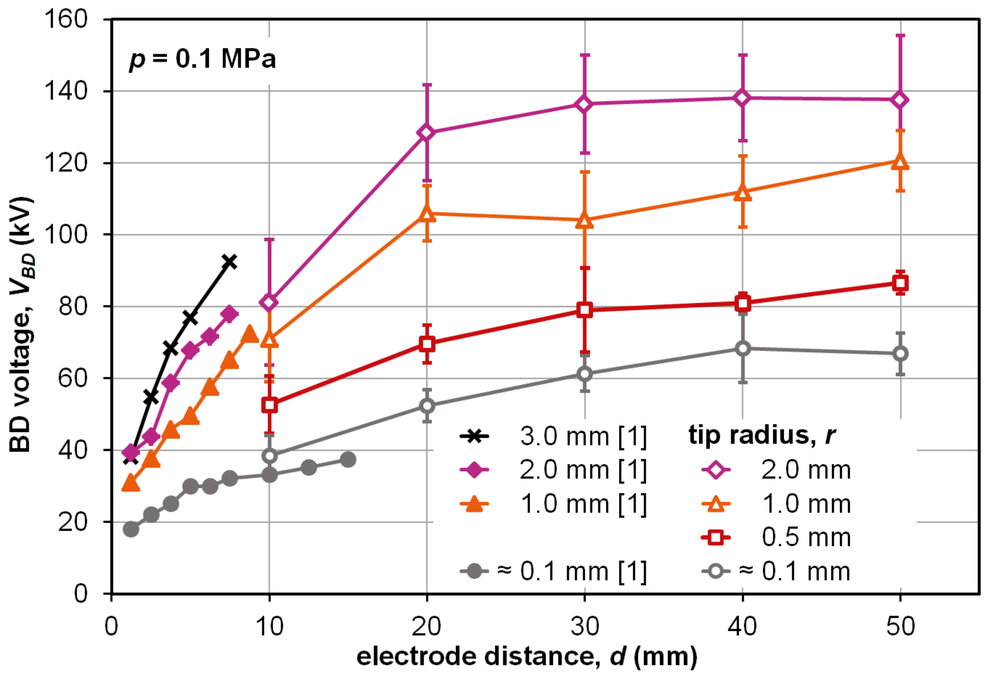
- Low mean BD strength of 2 – 8 kV/mm for non-uniform fields instead of 10 – 100 kV/mm in the case of uniform electric fields
- For r = 0.5 mm roughly 10% increase of BD strength per 0.1 MPa
- For r = 1.0 mm and r = 2.0 mm no significant increase



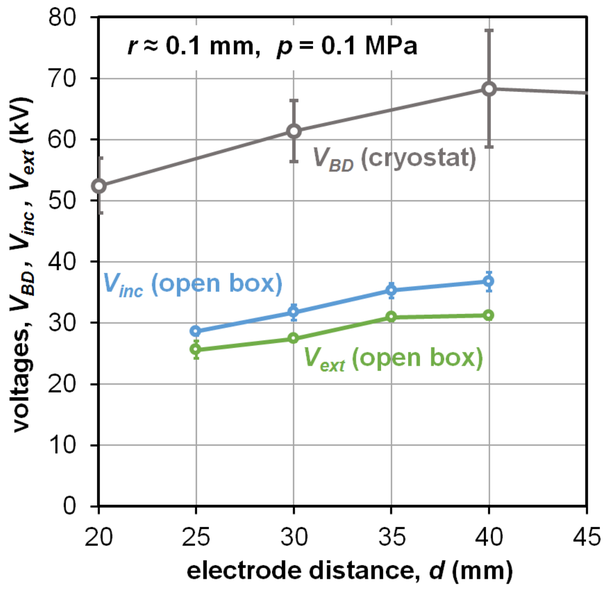
- Maximum BD strength at the high voltage tip electrode nearly independent of electrode distance
- Higher maximum BD strength for smaller tip radius due to area and volume effect

Partial Discharges

Breakdown at normal pressure



[1] M. Haerst; R. Bonin, C. Humpert (2016): Breakdown characteristics of liquid nitrogen in strongly inhomogeneous electric fields. In: IEEE Trans. Appl. Supercond. 26 (3)



$r \approx 0.1$ mm ($\eta < 0.03$)

- Inception voltage roughly at 50 % of BD voltage
- Extinction voltage roughly at 87 % of inception voltage
- High apparent charge of 3000 pC

r = 0.5 ... 2.0 mm ($\eta \geq 0.03$)

- No partial discharges
- BD without pre-discharges

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Laboratory of High Voltage Engineering
Institute of Electrical Power Engineering
TH Köln (University of Applied Sciences)
Betzdorfer Straße 2, 50679 Köln, Germany

Contact: Prof. Dr.-Ing. Christof Humpert
christof.humpert@th-koeln.de

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