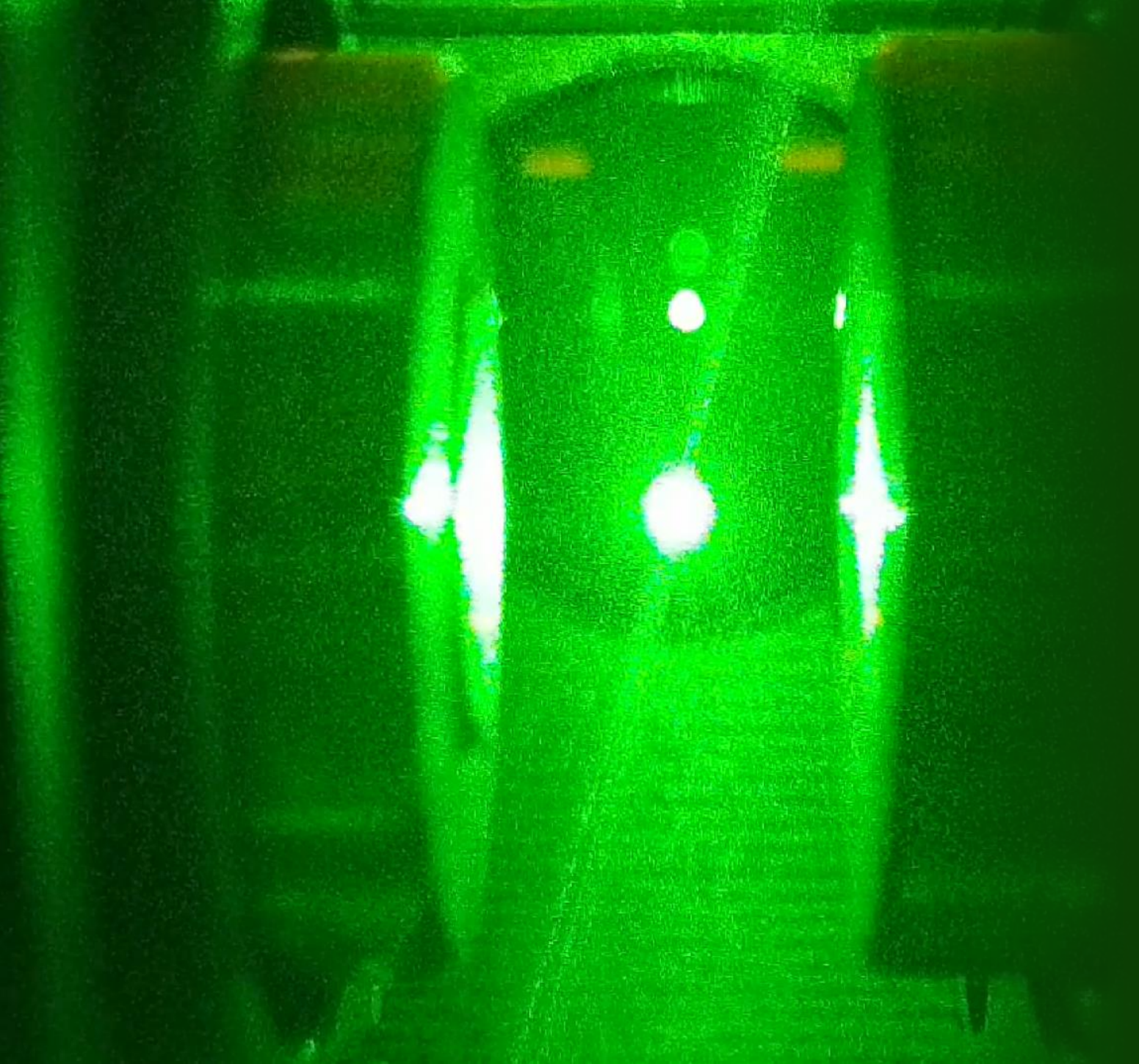

Measuring self-induced corona discharges of individual aerosol particles in an optical trap

Andrea Stoellner

I.C.D. Lenton, C. Muller and S. Waitukaitis

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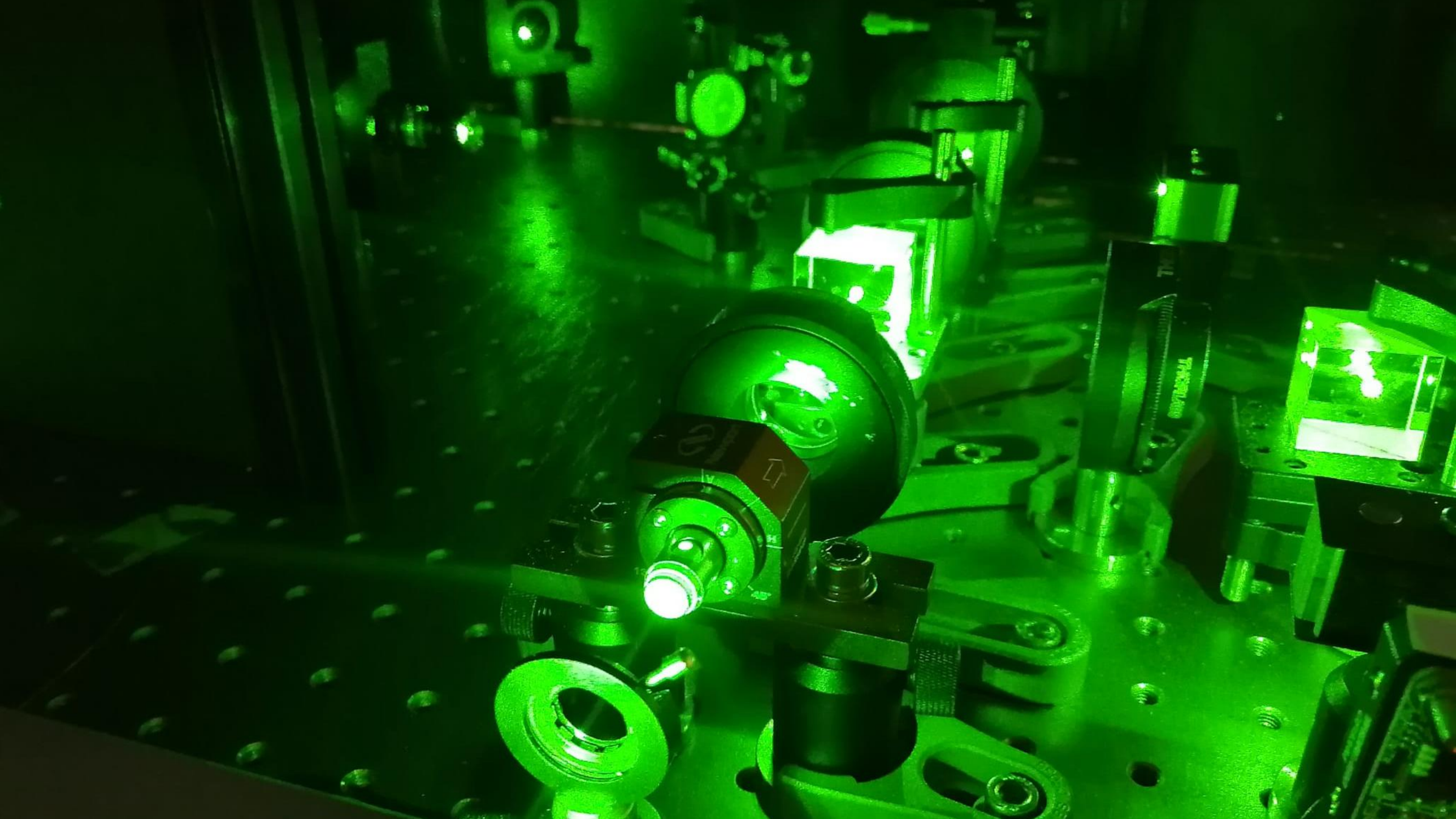



How is lightning triggered?

Electric fields in thunderclouds are smaller than breakdown field of air (3000 kV/m)

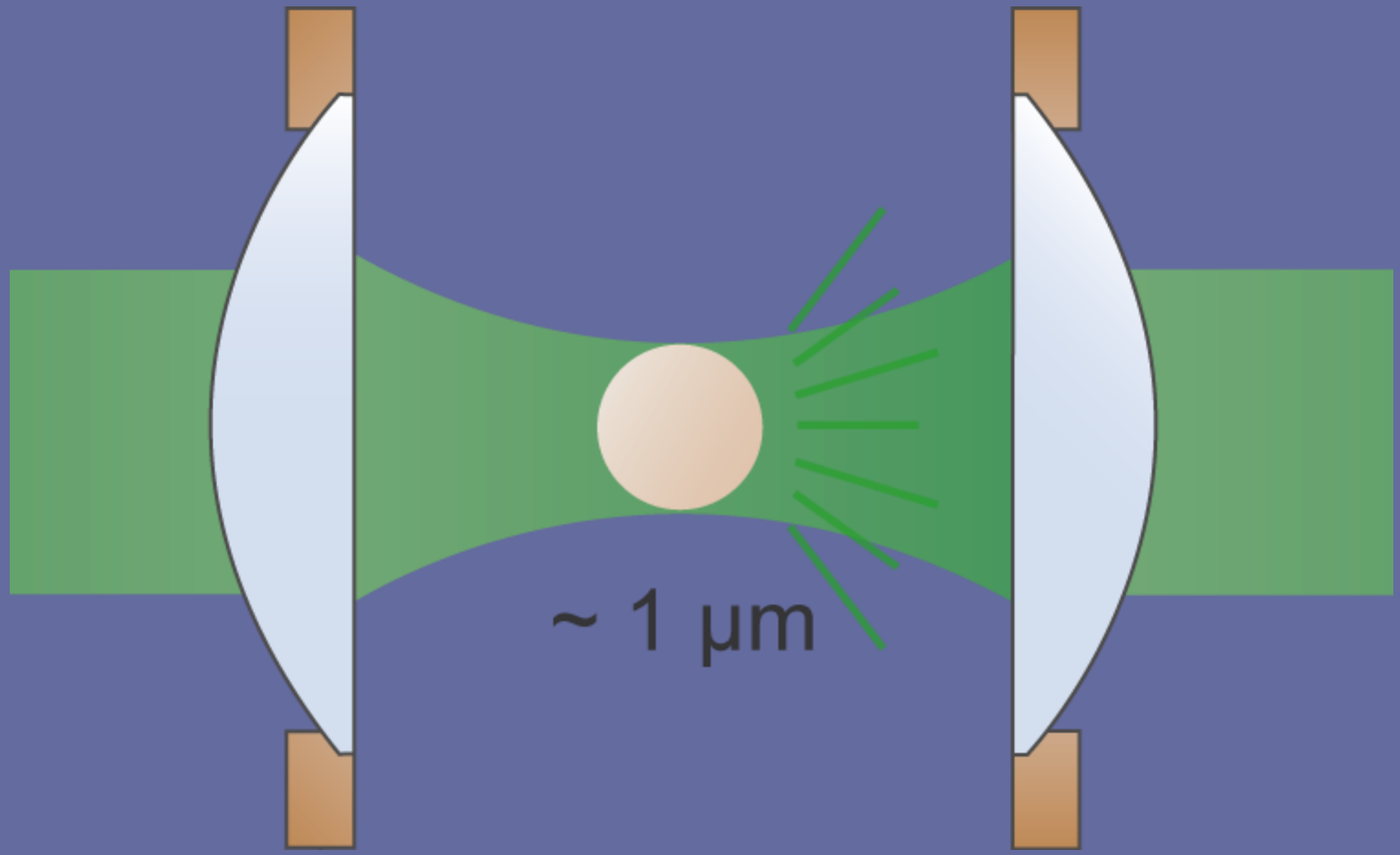
Reference	Type of measurement	Maximum electric field (kV/m)	Altitude of maximum electric field (km)	Sea-level equivalent electric field (kV/m)
Gunn [79]	Aircraft	340	3.93	540
Winn and Moore [80]	Rocket	60	5.5	110
Winn et al. [81]	Rocket	400	6	810
Winn et al. [82]	Balloon	1000	6	2000
Weber et al. [83]	Balloon	100	8	260
Fitzgerald [84]	Aircraft	120	8.8	340
Stolzenburg et al. [91] (i)	Balloon	78.7	11.5[e]	309[e]
Stolzenburg et al. [91] (ii)	Balloon	115	8.4	310
Stolzenburg et al. [91] (iii)	Balloon	245[e]	8.4	665[e]
Stolzenburg et al. [91] (iv)	Balloon	97.5	10.1	327
Stolzenburg et al. [91] (v)	Balloon	118.6	8.6	331
Stolzenburg et al. [91] (vi)	Balloon	135.9	7.6	336
Stolzenburg et al. [91] (vii)	Balloon	79.0	13.1	376
Stolzenburg et al. [91] (viii)	Balloon	87.9	13.0	413
Stolzenburg et al. [91] (ix)	Balloon	135.2	10.0	445
Stolzenburg et al. [91] (x)	Balloon	127.0	13.4	626
Stolzenburg et al. [91] (xi)	Balloon	195	12.2[e]	833[e]
Stolzenburg et al. [91] (xii)	Balloon	220[e,s]	12.1[e]	929[e]

[e] Estimated values.
[s] Measurement was saturated.

J. R. Dwyer, & M. A. Uman (2014). The physics of lightning. *Physics Reports*, *534*, 147–241.

Optical tweezers

1. single particle (1µm SiO_2)
2. precise charge measurement
3. no interference from substrate or sample holder



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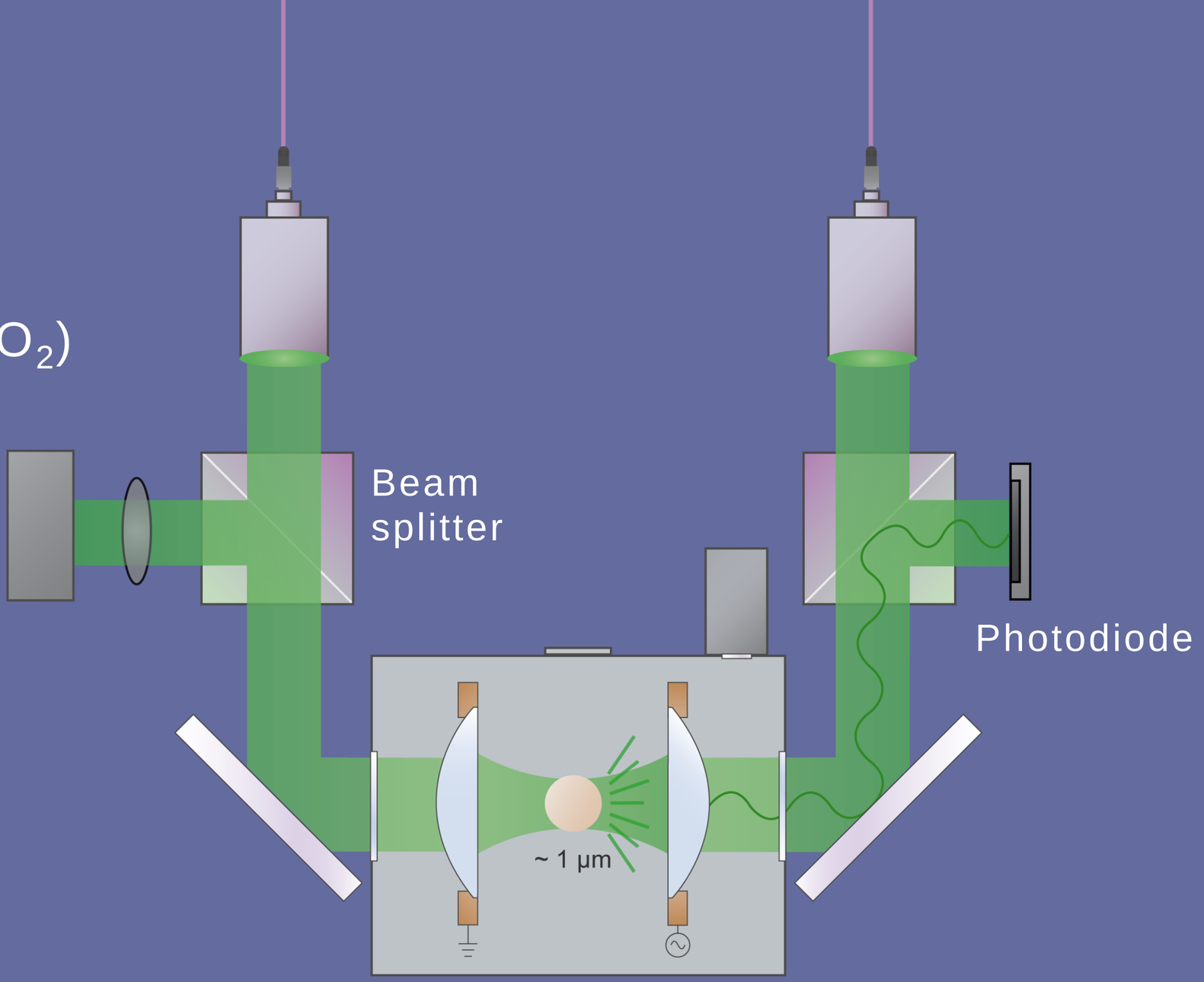
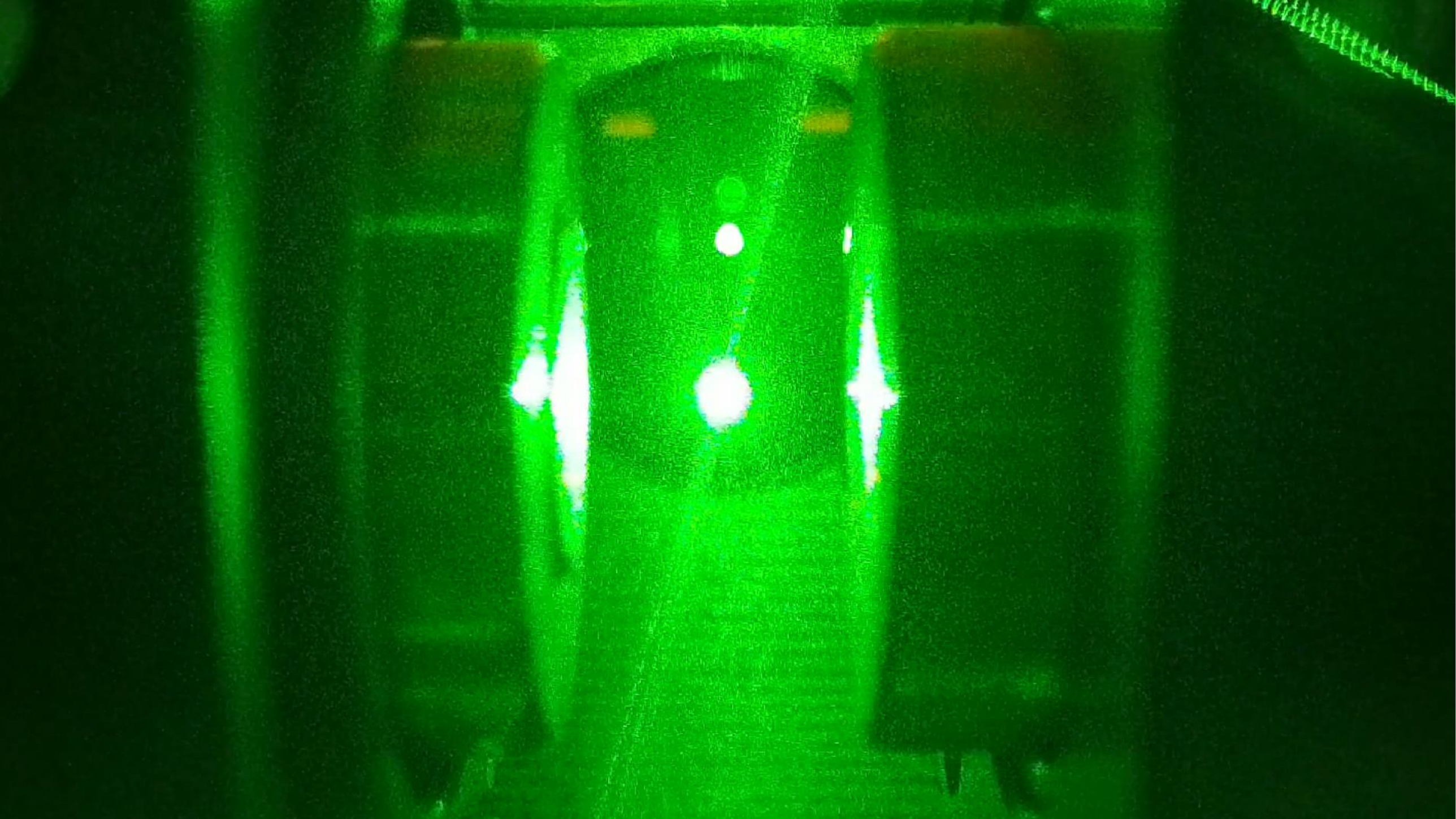
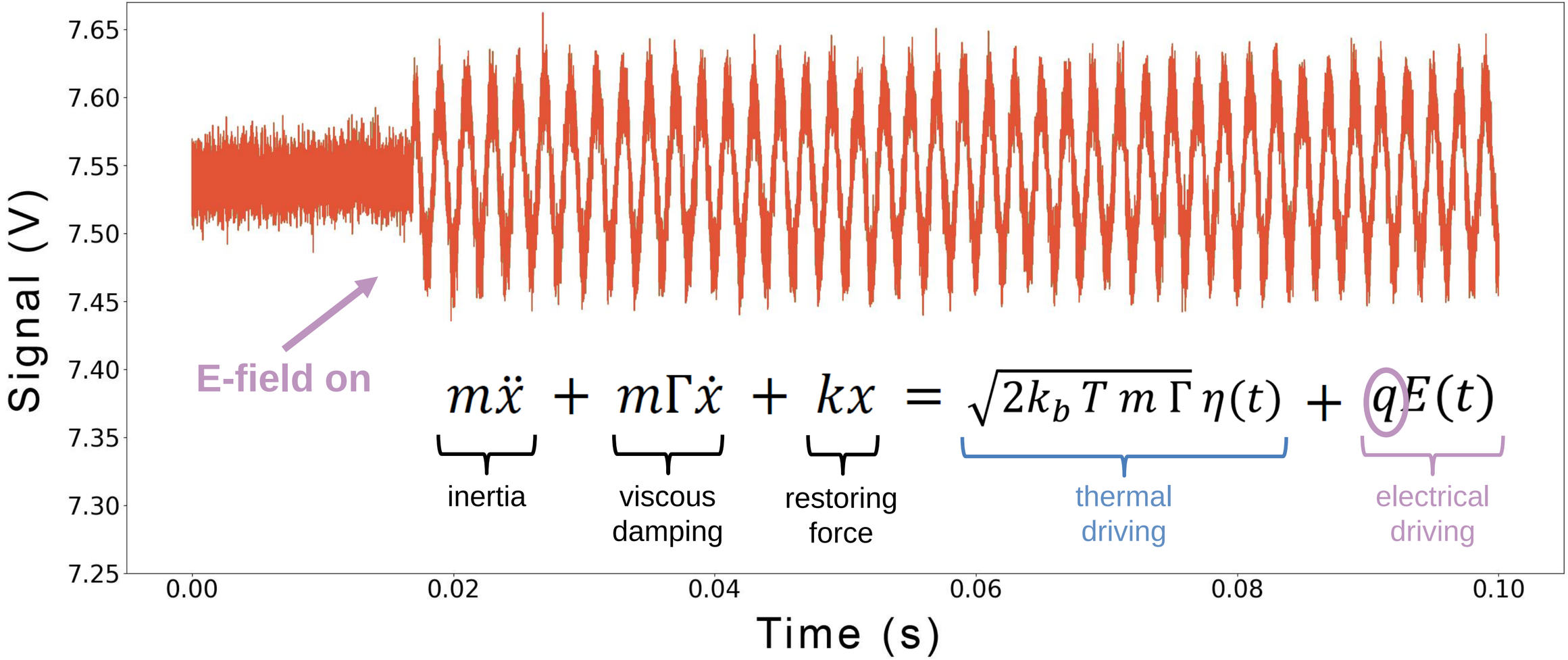


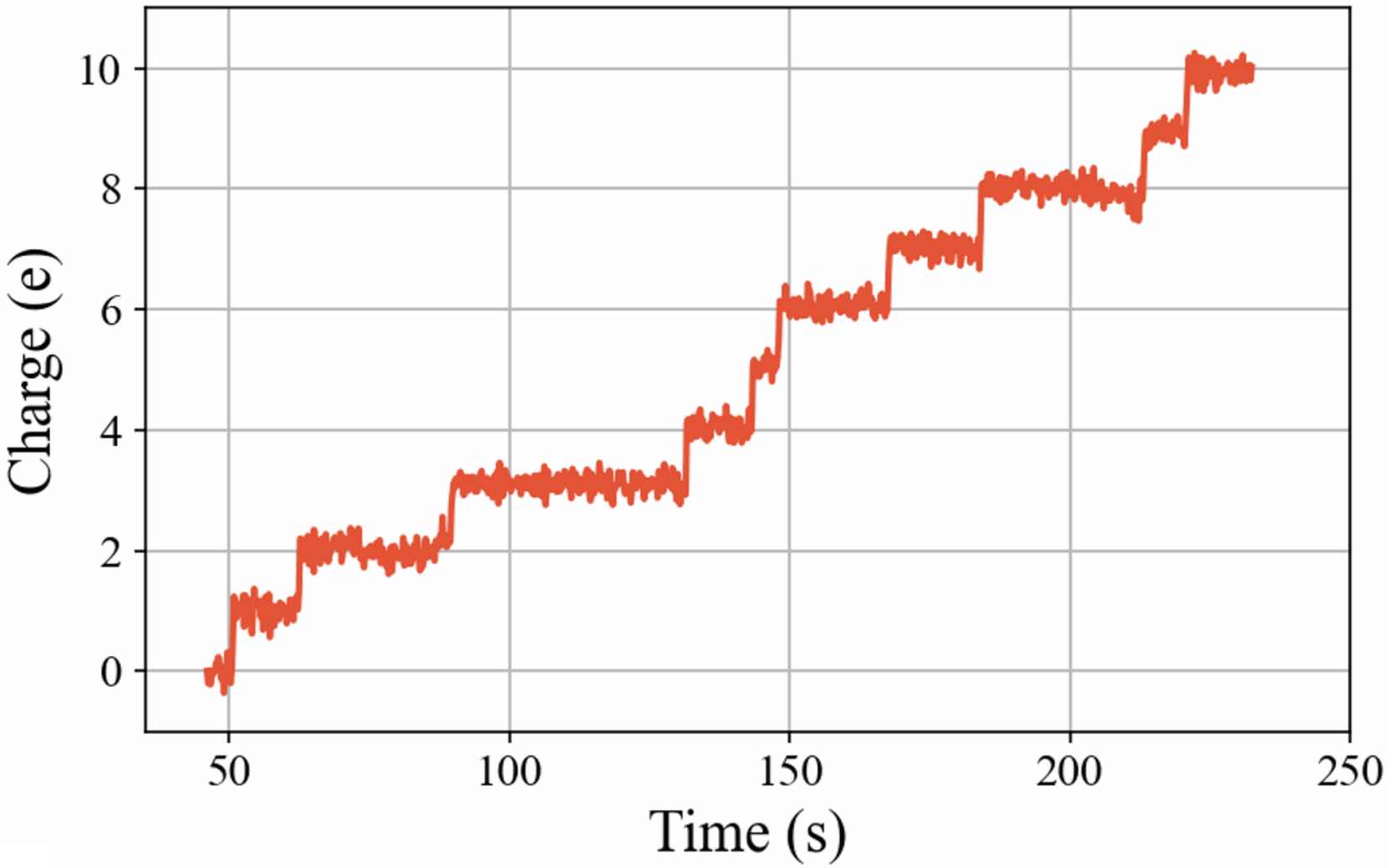


Electric driving + equation of motion

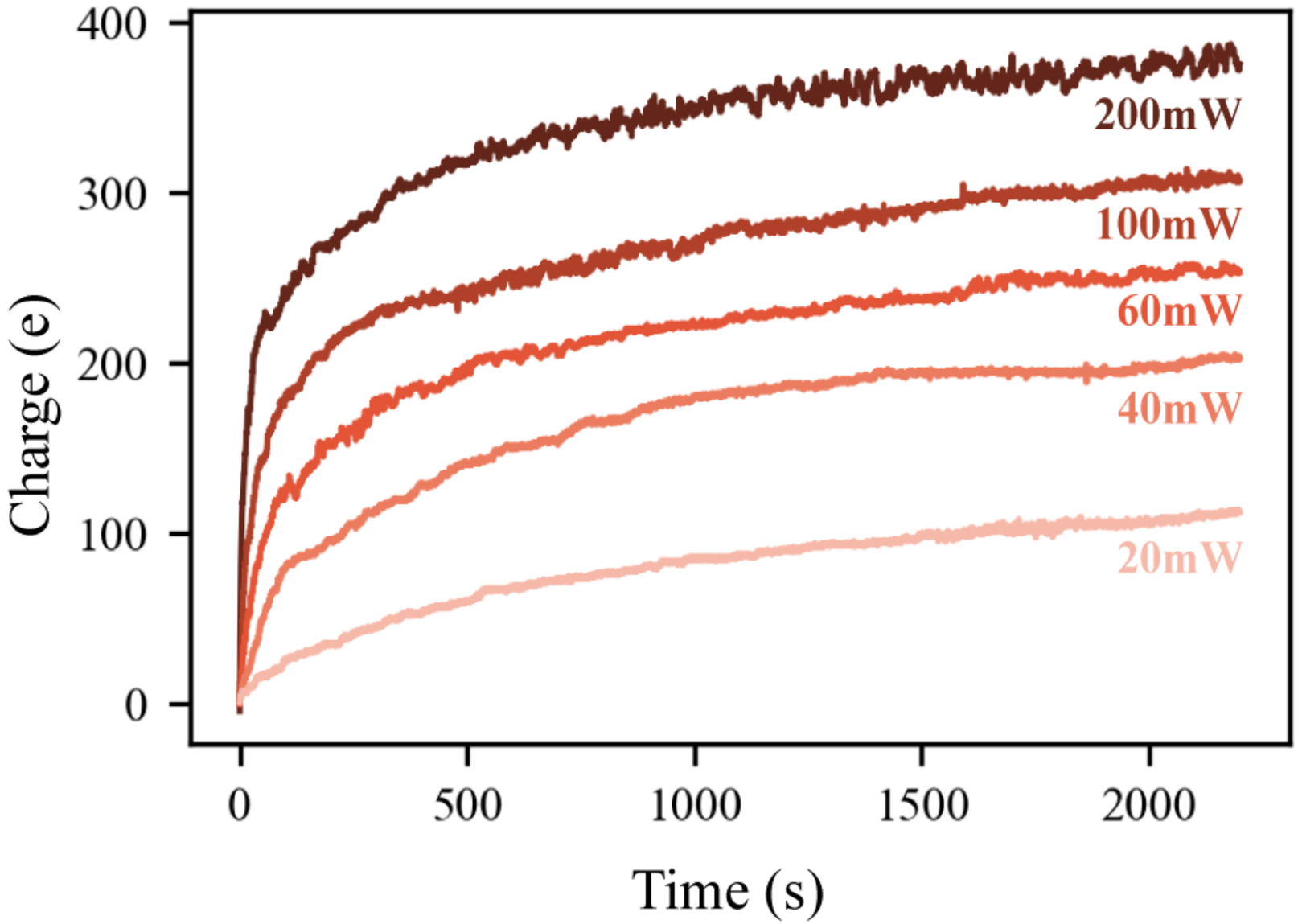


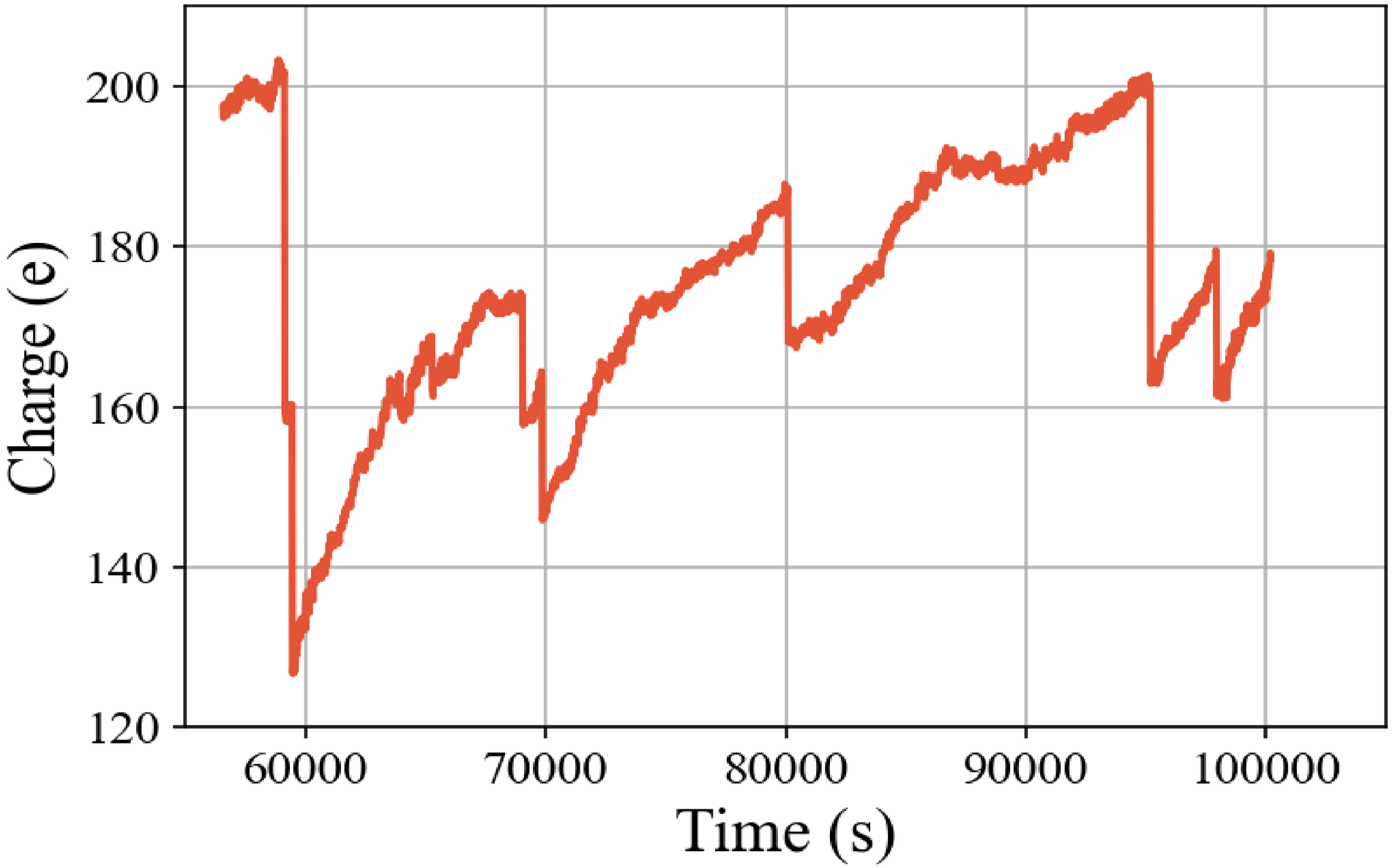
Ricci et al. (2019). Accurate mass measurement of a levitated nanomechanical resonator for precision force-sensing. *Nano Letters*, *19*(10), 6711–6715.

Elementary charge resolution on a single aerosol particle



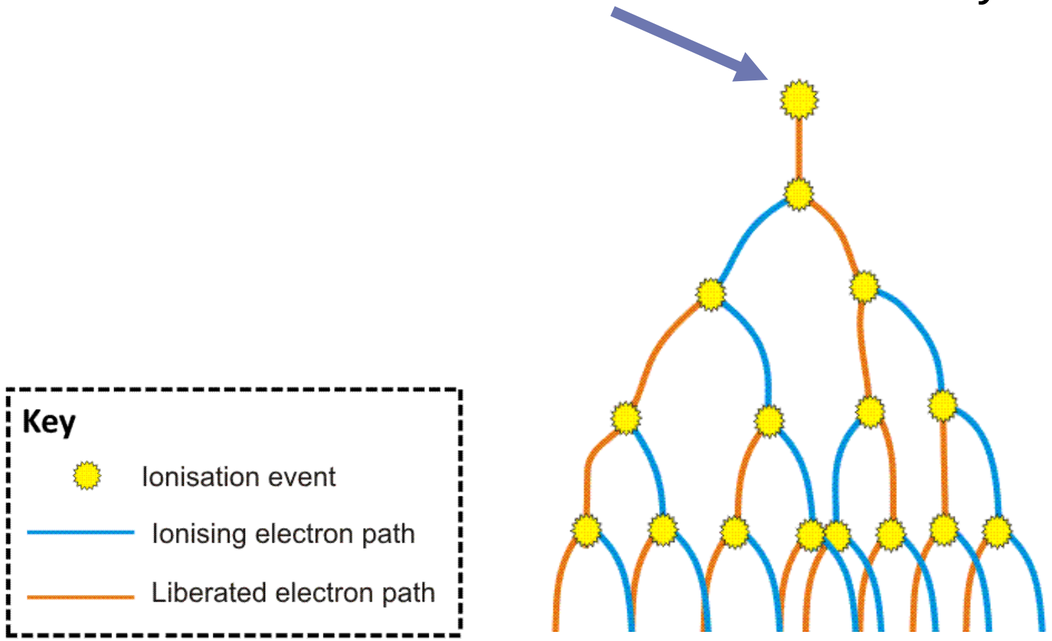
More laser power → faster charging




Charge (e)
200
180
160
140
120
60000
70000
80000
90000
100000
Time (s)

Relativistic Runaway Electron Avalanches

relativistic electron from cosmic ray



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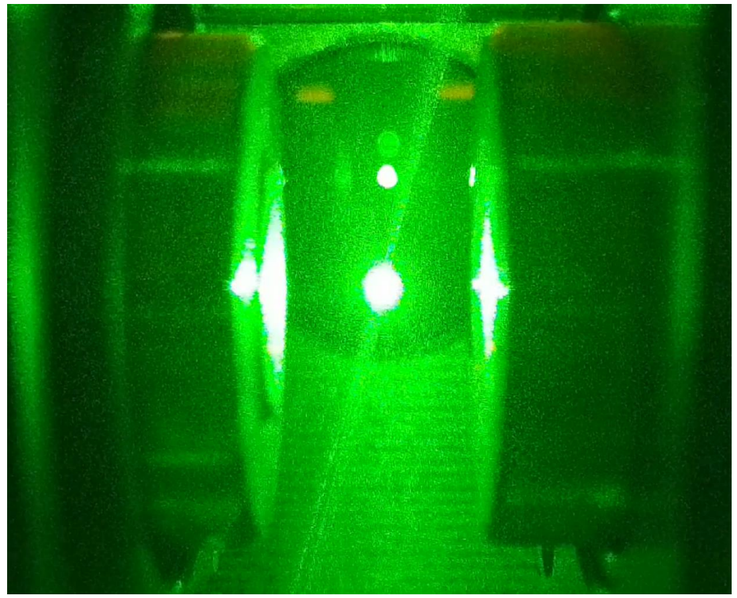
Corona discharge from hydrometeors

Petersen *et al.* (2014)

Previous studies of hydrometeor corona discharge

Macky (1931)
Richard & Dawson (1971)
Griffiths & Latham (1974)
Coquillat *et al.* (2003)
Petersen *et al.* (2014)
Peeters *et al.* (2022)
…

~500 kV/m



~10 kV/m

Caveats

Our particle is very small
~ 1 μm

- Try the same with bigger particles
- Try with actual ice

There’s a long way from corona discharge to lightning bolt.

- Potential source of streamers
- Locally enhance conductivity and electric fields

Conclusion

- Single particle charge measurement with elementary charge resolution

Corona discharge is possible:

- at very low background fields
- on spherical particles with no sharp geometrical features

More measurements are undergoing!

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