Discharge propagation in GEM detectors

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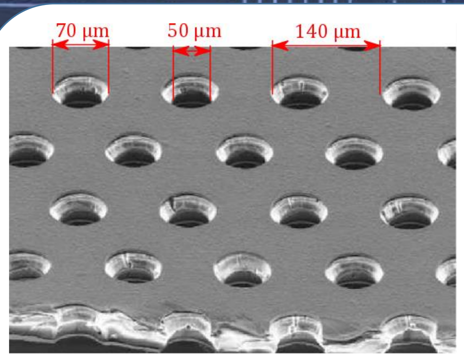
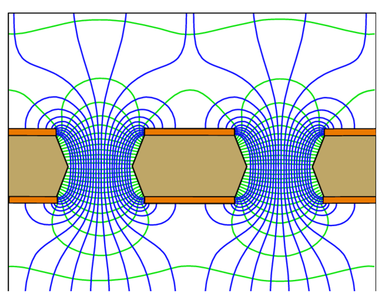
1. Introduction

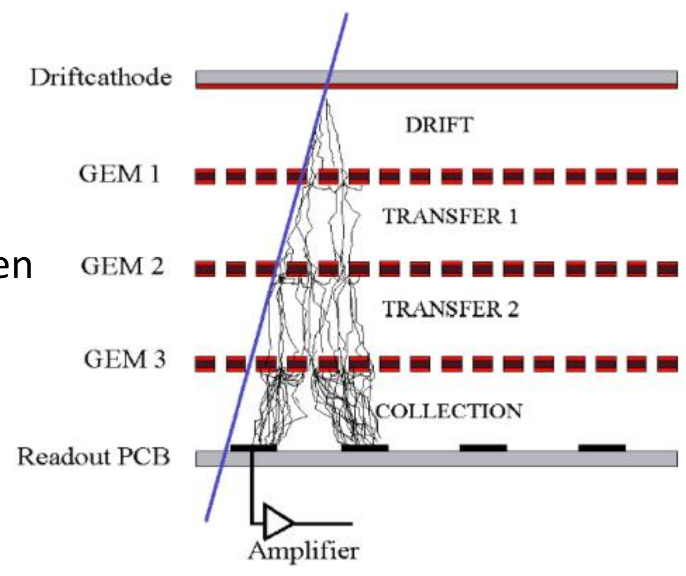
Micropattern gaseous detectors (MPGDs) are a group of modern gaseous ionizing detectors consisting of microelectrode structures developed to overcome many of the difficulties of traditional gaseous detectors such as multiwire proportional chambers. The gas electron multiplier (GEM) is one of the most prolific MPGDs currently in use and is slated to be used for many future detectors or current detector upgrades. Propagating discharges (PDs) to the readout plane are a potential threat to the stable operation of GEM detectors and can cause permanent damage to the detector. An experimental setup enabling simultaneous electrical and optical measurements is used to provide new insights regarding the physical mechanism of the delayed discharge, including the microsecond time delay between the primary and secondary discharges. Based on these measurements, indicators of the onset of the delayed propagating discharge are identified by means of the charge transfer to the readout electrode.

2. GEM

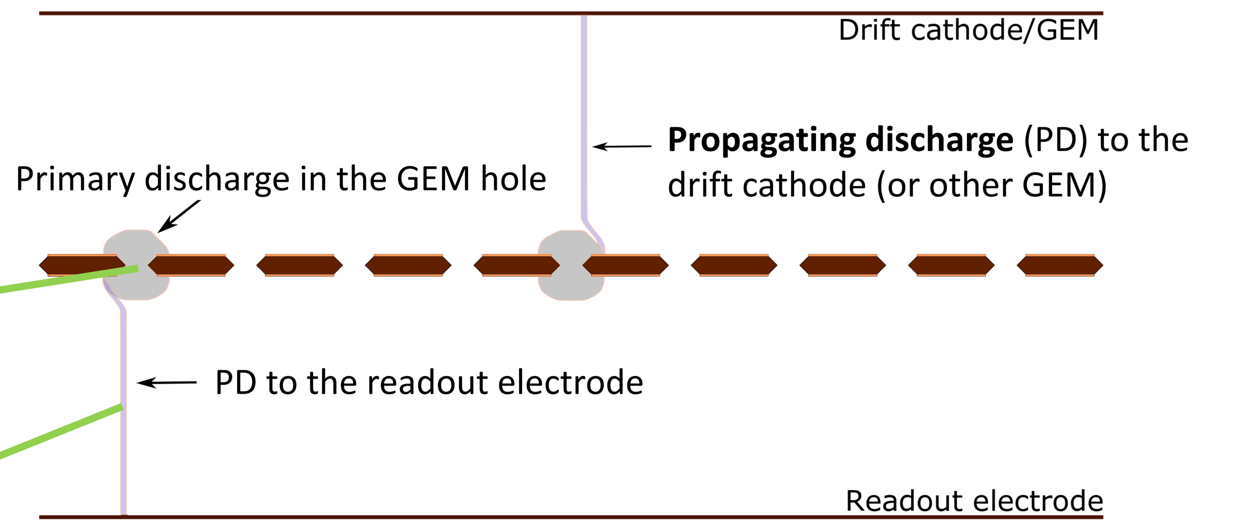




- Gaseous detector used for electron multiplication
- Dielectric sandwiched between layers of copper with many holes
- Potential difference between copper layers causes a high electric field in the holes
- Electrons cause an avalanche in the holes
- Several GEMs in series cause multiplicative gains



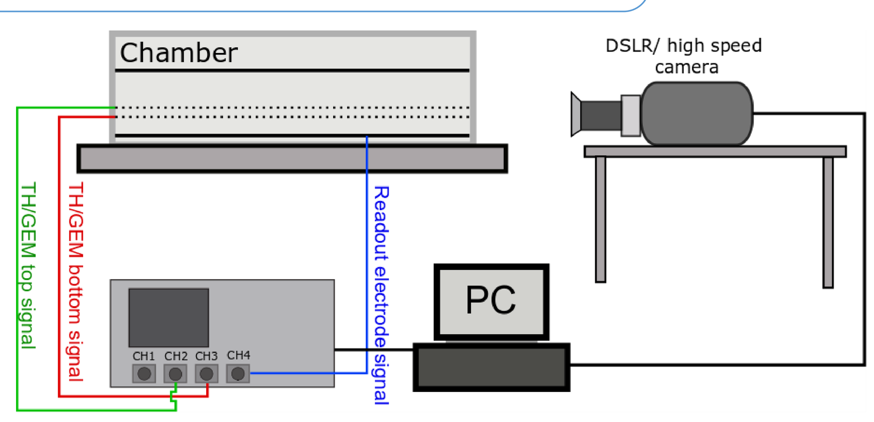
3. GEM Discharges

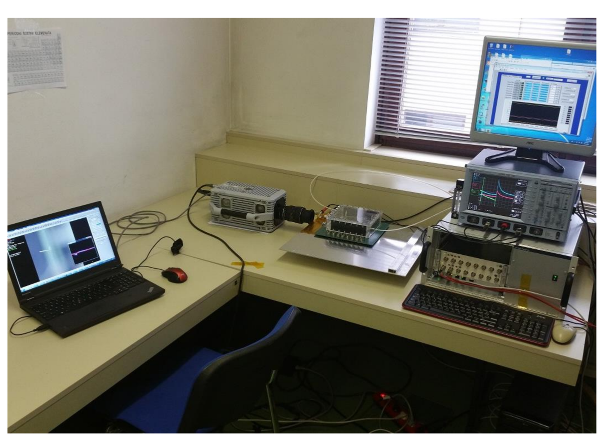


- A primary discharge occurs due to high ionization inside a GEM hole
  - Not dangerous for the long term operation of the detector
- At high enough electric fields values, a primary discharge can cause a propagating discharge (PD) to a nearby electrode
- This PD occurs with a $1 - 100\ \mu s$ time delay after the primary discharge
- The physical mechanism of the PD is not understood
- A PD to the readout electrode is dangerous and can destroy electronics
- **Goal: understand the physical mechanism of the delayed PD**

4. Experimental Setup

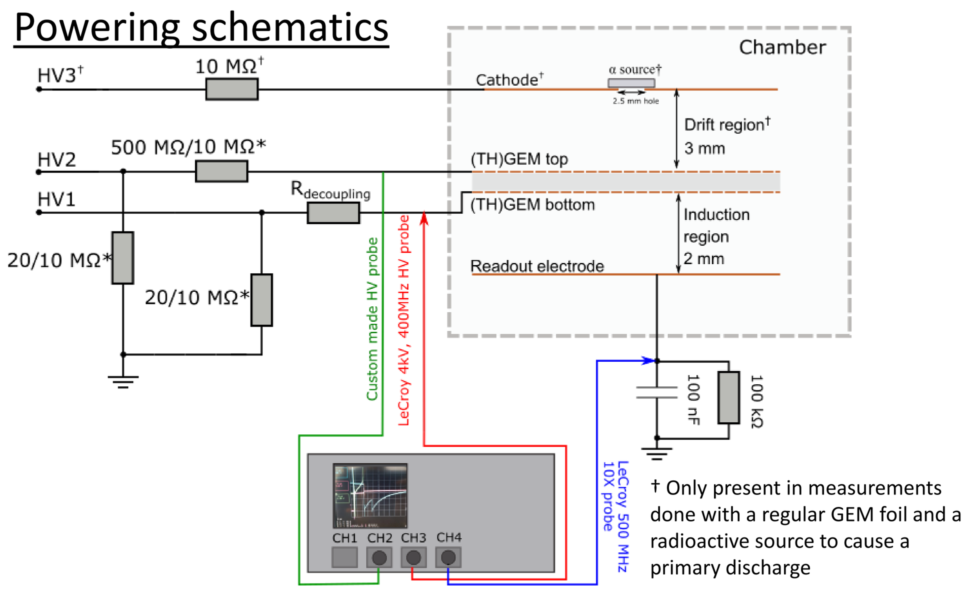
- Three electrical signals were recorded:
  - GEM top electrode
  - GEM bottom electrode
  - Readout electrode





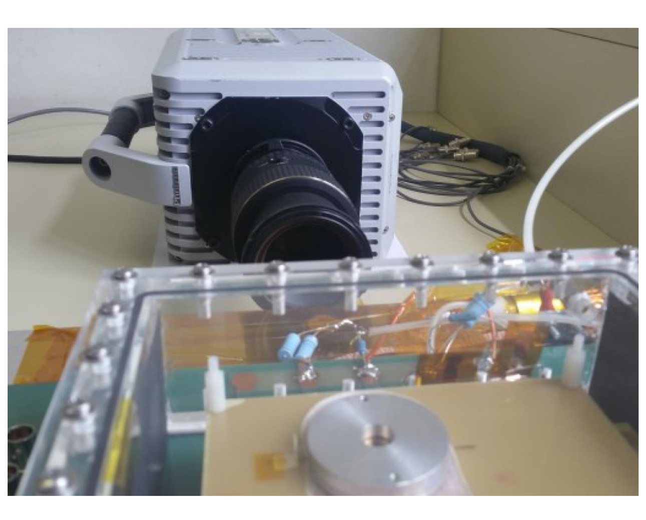
- Data from the oscilloscope and the digital camera were recorded simultaneously to correlate the electrical and the optical measurements

Powering schematics



- The readout electrode was connected to GND over a parallel connection of a 100 nF capacitor and a 100 kΩ resistor to determine the current in the induction region:

$$i(t) = C\frac{du}{dt}$$

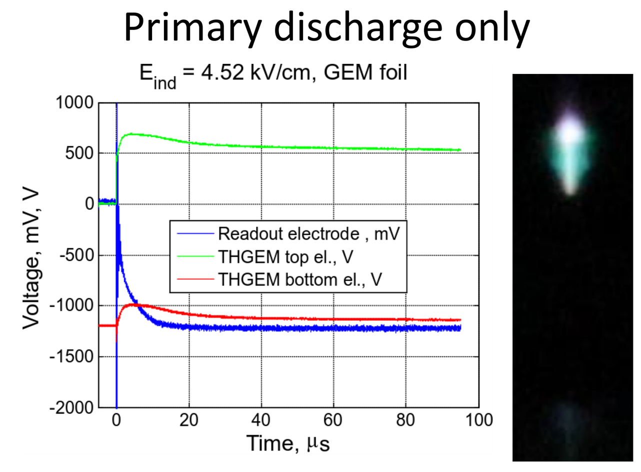


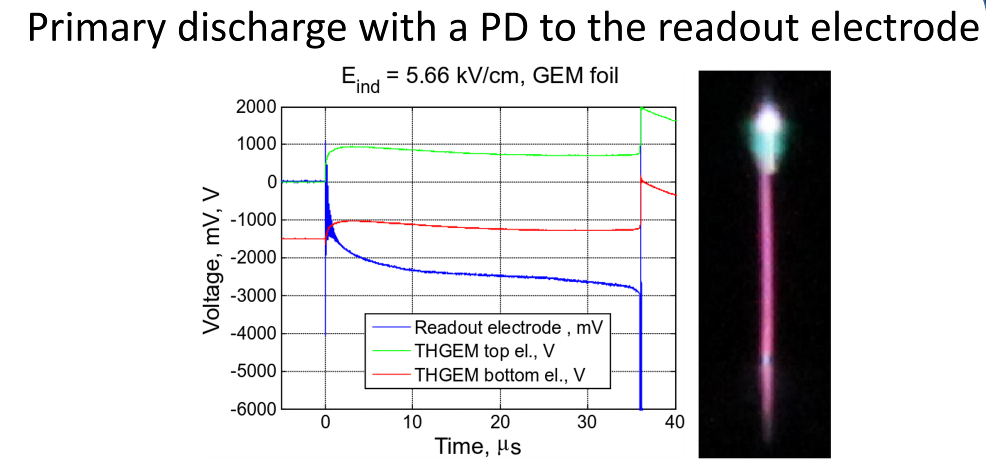
- Optical measurements were done with a DSLR as well as a high speed camera:

Photron FASTCAM SA-X2 Type 1080 K:

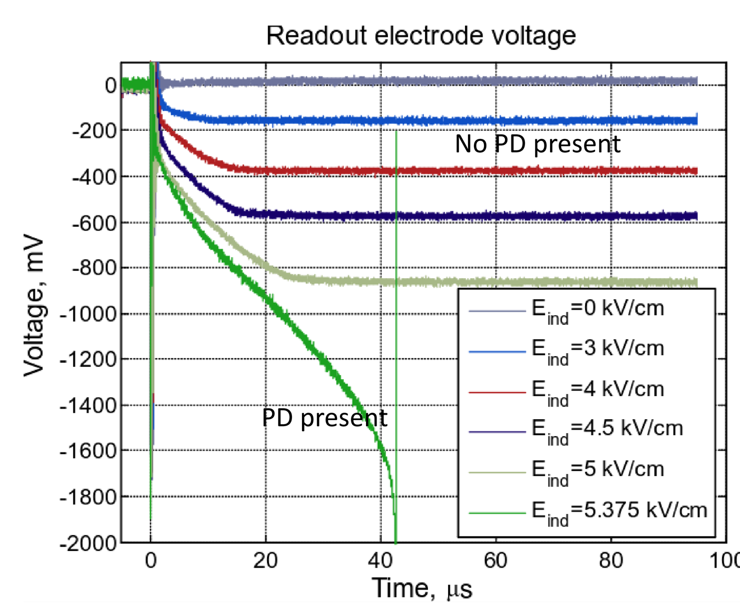
- 1-Megapixel CMOS Colour Image Sensor Maximum Frame Rate: 1,080,000 fps ISO 10 000, minimum exposure 293 ns, trigger input TTL 5V
- Resolution: 128 x 40 (h x v pixels)~ 540,000fps, 128 x 8 (h x v pixels) ~1,080,000fps
- Tokina 100 mm F2.8 macro lens

5. Measurements



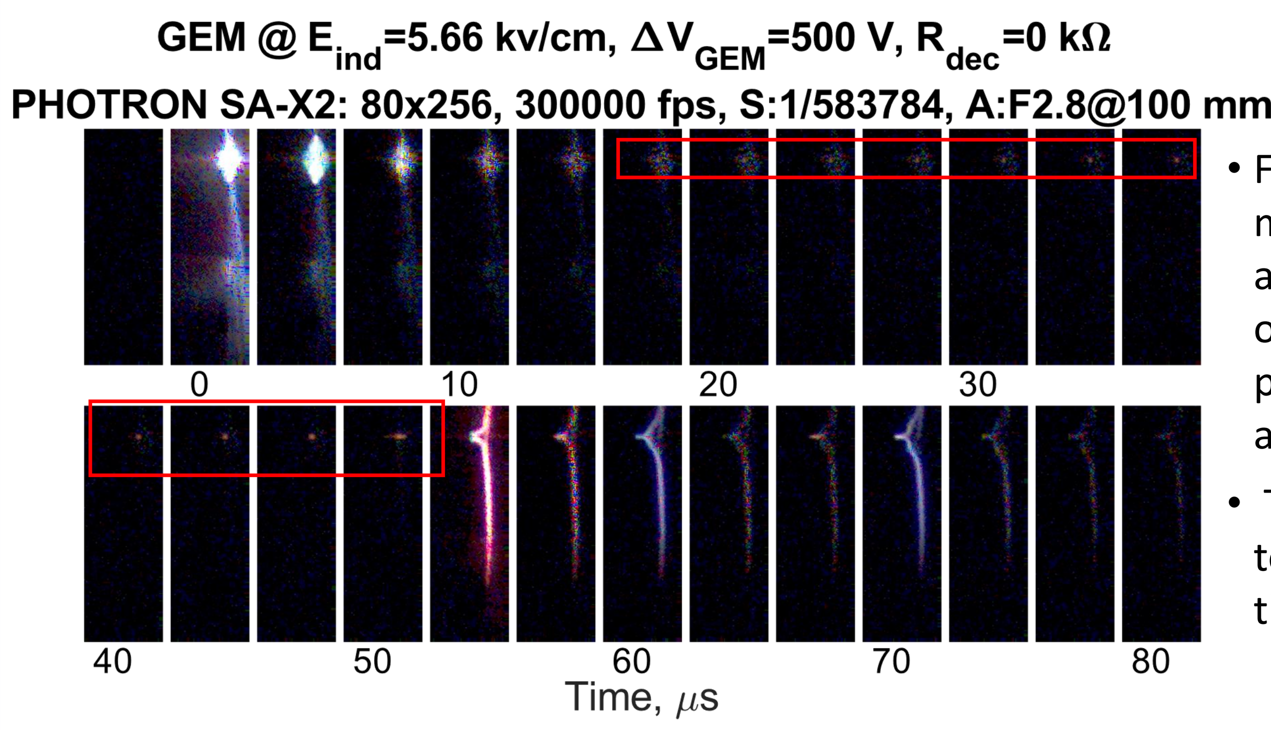


- Charge build-up on the readout electrode is observed even with no PD present suggesting that even at moderately low induction field values, right after the primary discharge there is initially a current passing through the induction region that decays with time



- Current in the induction region causes charge build-up on the readout electrode capacitor
- No PD: Higher order exponential fit
- PD: Spline fit
- Analytic derivation of the fit gives the current
- As the value of the induction field increases, the initial current in the induction region increases until a critical electric field value, where a PD occurs

- In events with a PD, the current in the induction region does not fall to zero but reaches a constant value before it starts to increase again approaching the PD

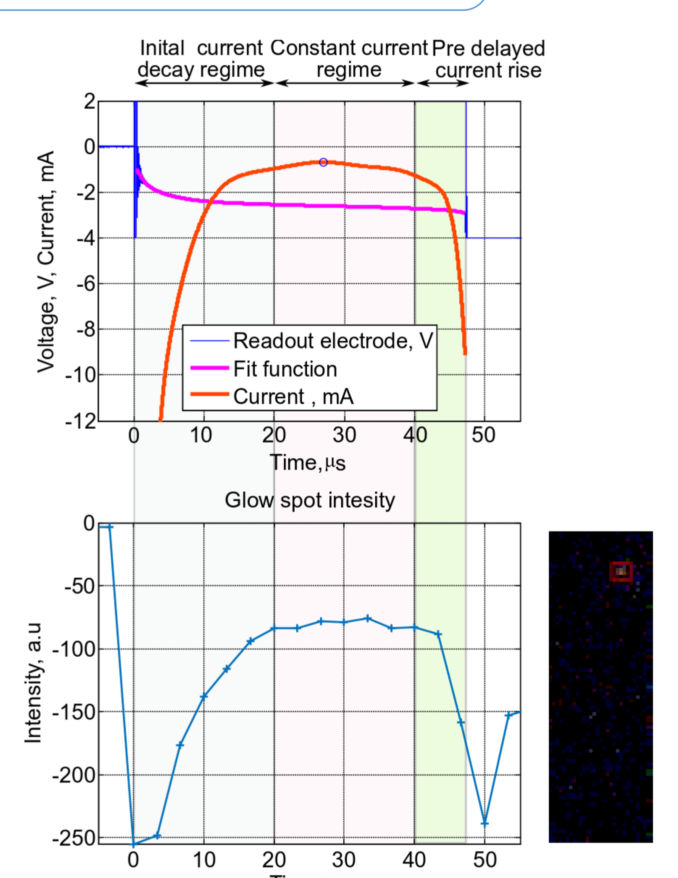


- Fast camera measurements uncover a red-hot glowing spot on the GEM near the primary discharge right after the primary occurs
- The PD is always shown to form connected to this glowing spot

Our hypothesis is that the current in the induction region comes from thermionic emissions from this glowing spot, causing it to further heat up. If the electric field is sufficiently high, the spot heats up faster than the heat can be dissipated causing the propagating discharge.

6. Intensity vs. Current

- Current in the induction region can be correlated to the intensity of the glowing spot
- The correlation reveals that the optical intensity of the glow follows the waveform of the current
- This suggests that the induction current originates from the glow at the bottom GEM electrode
- All three regimes that preceed the PD can be identified both in the optical and electrical measurements:
  1) The initial current decay after the primary
  2) The constant current regime
  3) The pre-delayed current rise
- The constant current regime is an indicator of the occurence of the delayed PD



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