

Development of a Projectile Probe

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Background

Probes, including Langmuir probes and magnetic probes, featured with low costs, simple fabrication and meanwhile high reliability and flexibility are extensively used in diagnostics

Perturbation by probe insertion

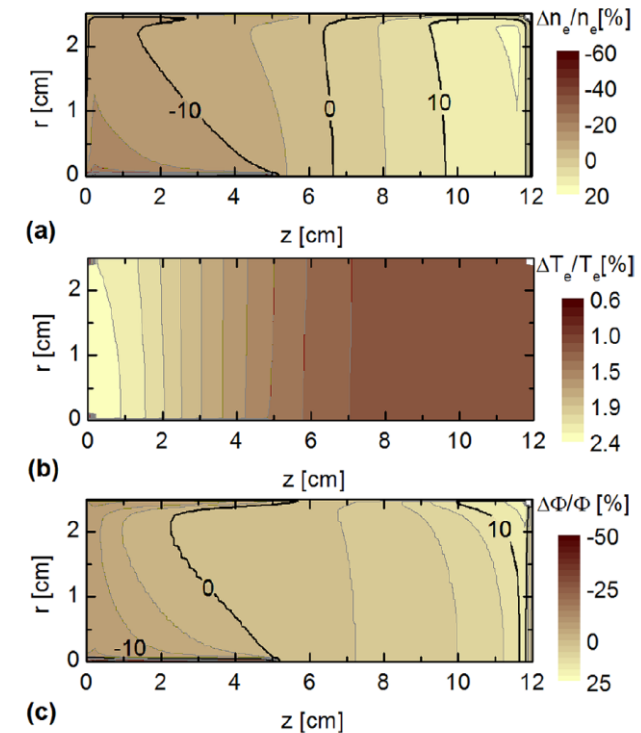
Insertion of probe, especially probe holder, will lead to a redistribution of plasma density and potential locally:

- up to 10% uncertainty of electron density and temperature [1]
- electron density decrease up to 30% [2]

A more flexible probe without holder?

➡ Projectile Probe

No support, floating in plasma, launched by electromagnetic launcher



Derivation of electron density and temperature and plasma potential caused by probe insertion (on x axis), figure from [1]

[1] D. Yordanov, St. Lishev, and A. Shivarova, "How does a probe inserted into the discharge influence the plasma structure?," *Journal of Applied Physics*, vol. 119, no. 18, p. 183302, May 2016, doi: 10.1063/1.4948981.

[2] O. Waldmann and G. Fussmann, "Influence of the Langmuir Probe Shaft on Measuring Plasma Parameters," *Contrib. Plasma Phys.*, vol. 48, no. 5–7, pp. 534–539, Jul. 2008, doi: 10.1002/ctpp.200810086.



Launcher Design

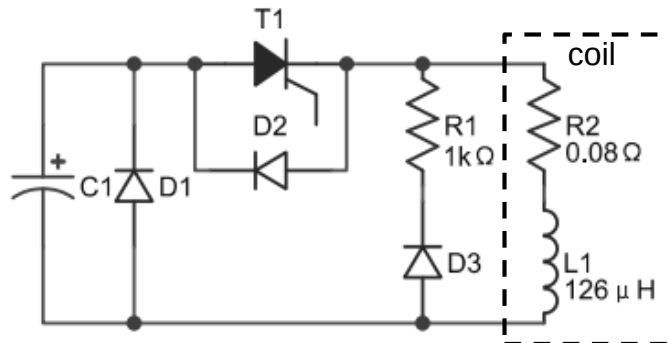
Mechanical Structure

Based on **reluctance accelerator**:

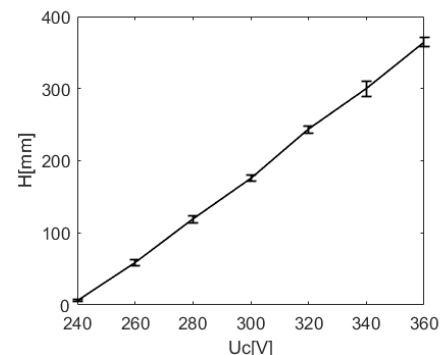
- Acceleration coil accelerates the ferromagnetic driving ring
- Driving ring thrusts the probe out, then decelerated by the deceleration coil
- The probe falls freely and is received by the horn collector

Driving System

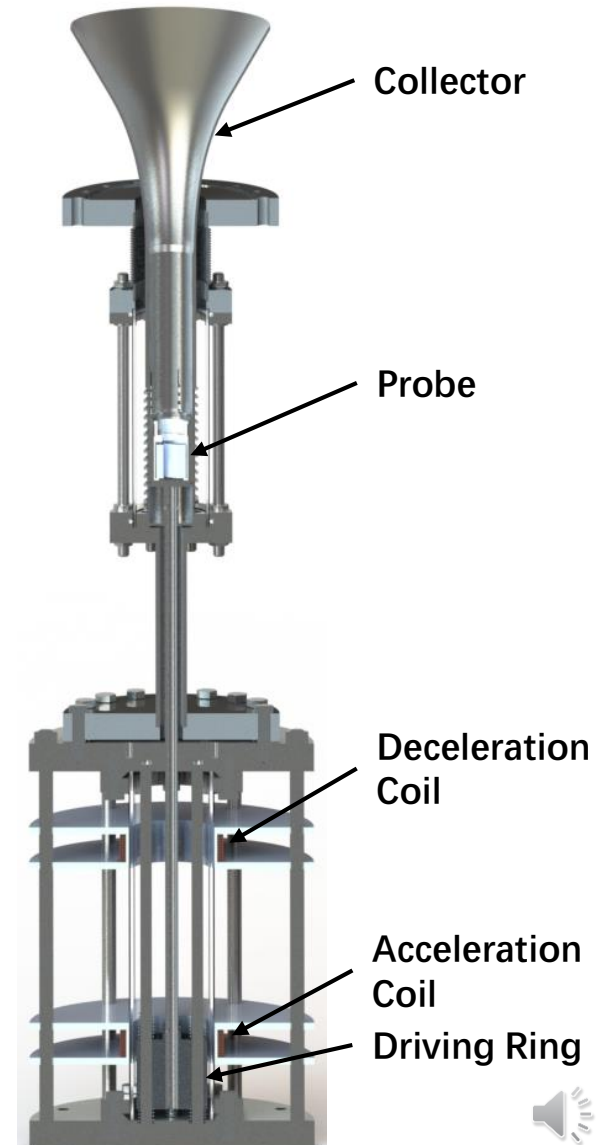
- Power supply: capacitor+thyristor
- $v_{out} < 4.2m/s$, $h < 0.4m$ (up to core plasma)



power circuit: with C1 of 6mF for acceleration and deceleration group, and 1mF for wakeup group



max probe height vs. capacitor voltage, the position accuracy is within 1cm



Probe Design

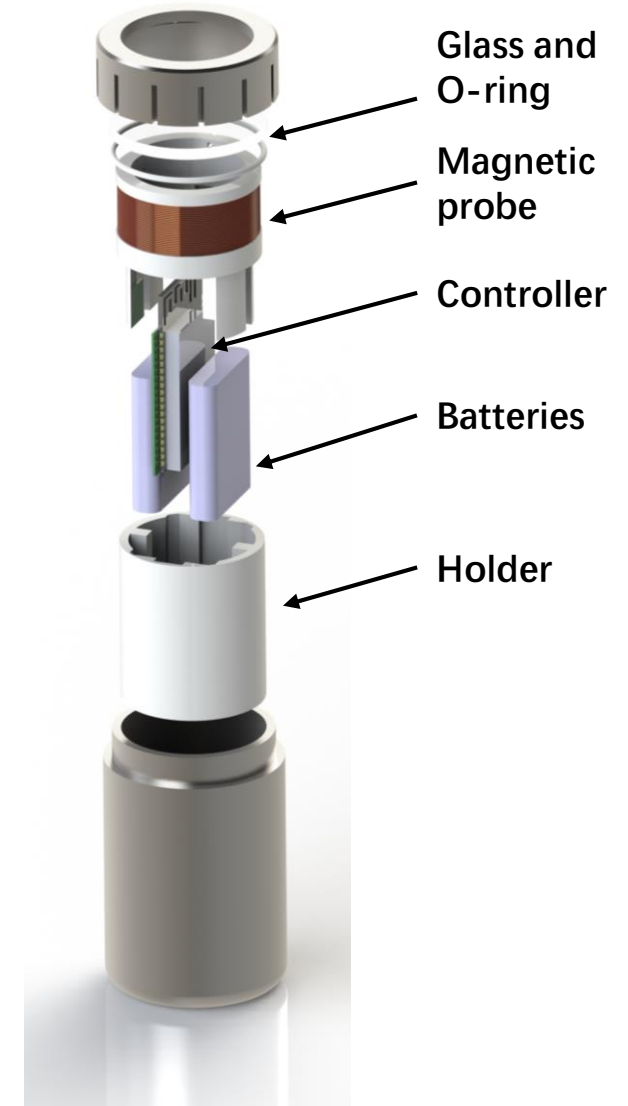
Compact design: $\Phi 3 \times 5 \text{cm}$, 316SS shell

Independent system: integrated with a magnetic probe head, a digitizer, a MCU capable of wireless communication, an accelerometer, and batteries

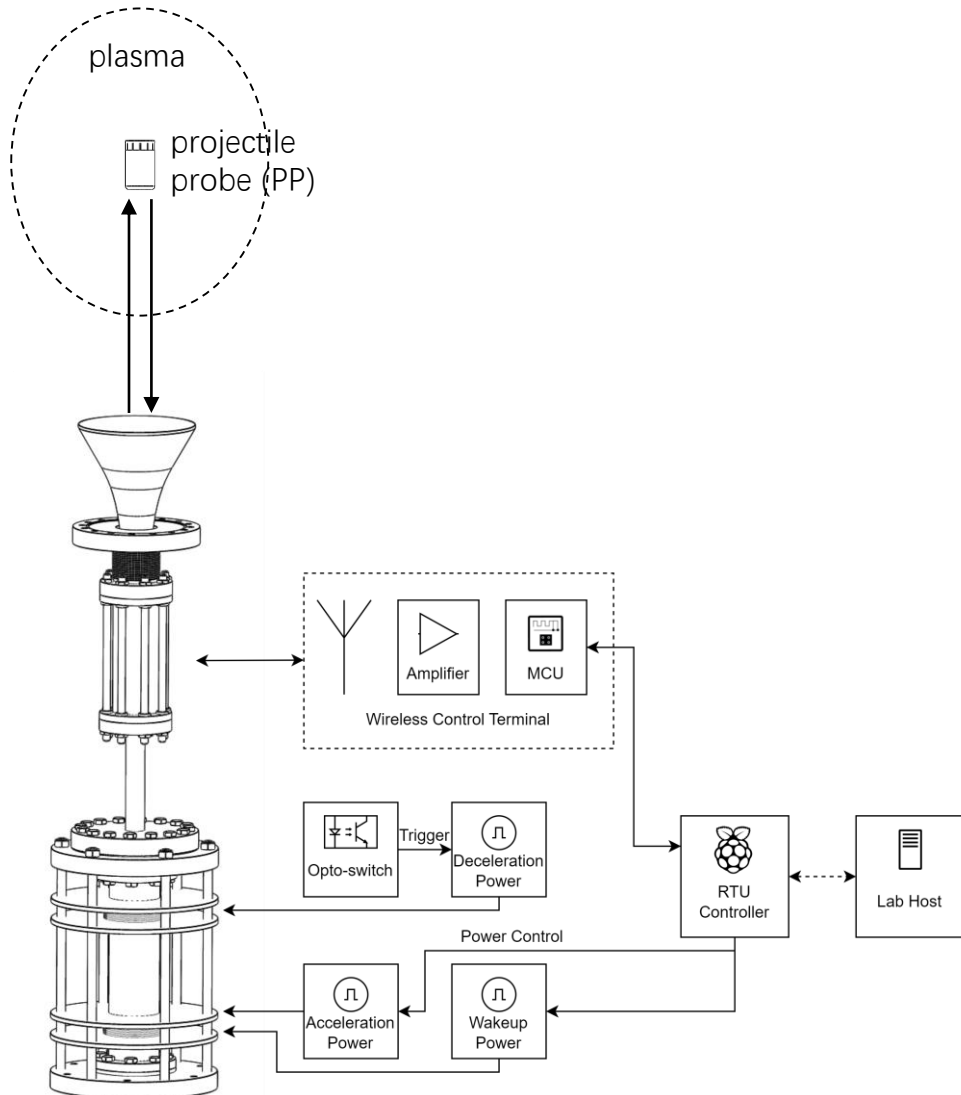
Low power consumption: $<10 \mu\text{A}$ current supply in sleep mode, work for 10s in every discharge, capable of over 1000 operations

- No net magnetic force and torque applied to probe by B_t or B_v
- Surface current introduced by plasma may cause probe rotation under B_v

Sample Rate	100ksps
Sample Depth	12bit
Duration	1s
Wireless Protocol	BLE4.2
Wakeup Source	accelerometer
On Board MCU	ESP32



Overview and Workflow



Phase1:

Wakeup power bank discharges to acceleration coil to trigger a shake. The probe wakeups and calibrates time

Phase2:

The probe is launched 100~200ms before tokamak discharge

Phase3:

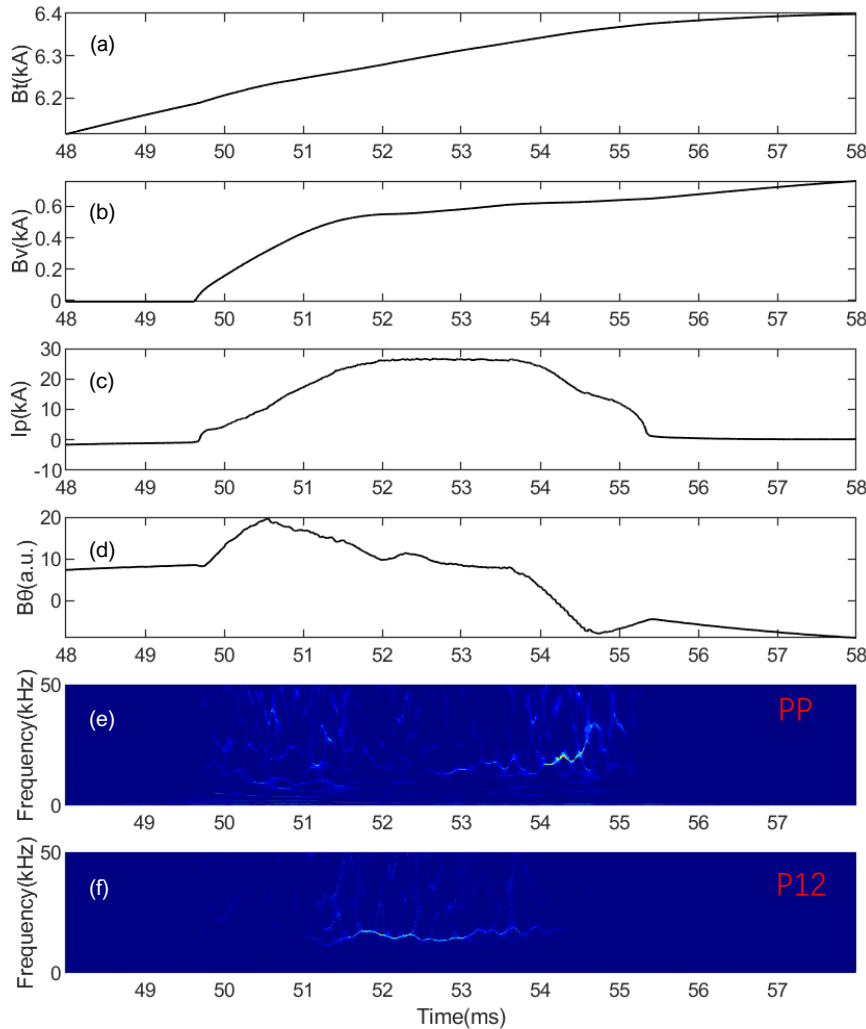
The probe reaches its top height and is quasi-static in discharge (~ 10 ms), collecting data

Phase4:

The probe falls back to its origin, transferring data to terminal outside, and then goes to sleep.



Installation and Test

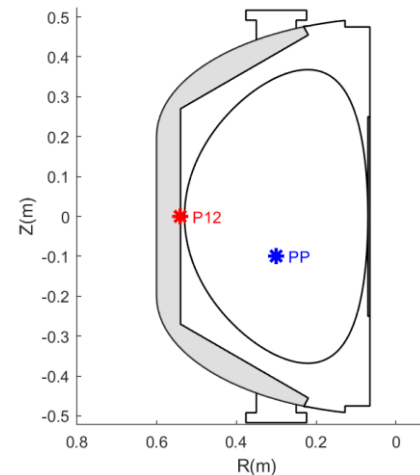


Preliminary Results

- Strong MHD activity (~ 20 kHz) at boundary, shown from poloidal magnetic probe P12, meanwhile quiet at core, shown from projectile probe (PP)
- Move inside when plasma current begins to ramp down

Future Work

- A detailed evaluation of influence by PP insertion
- Performance upgrade



Thank you and welcome discussion!

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