

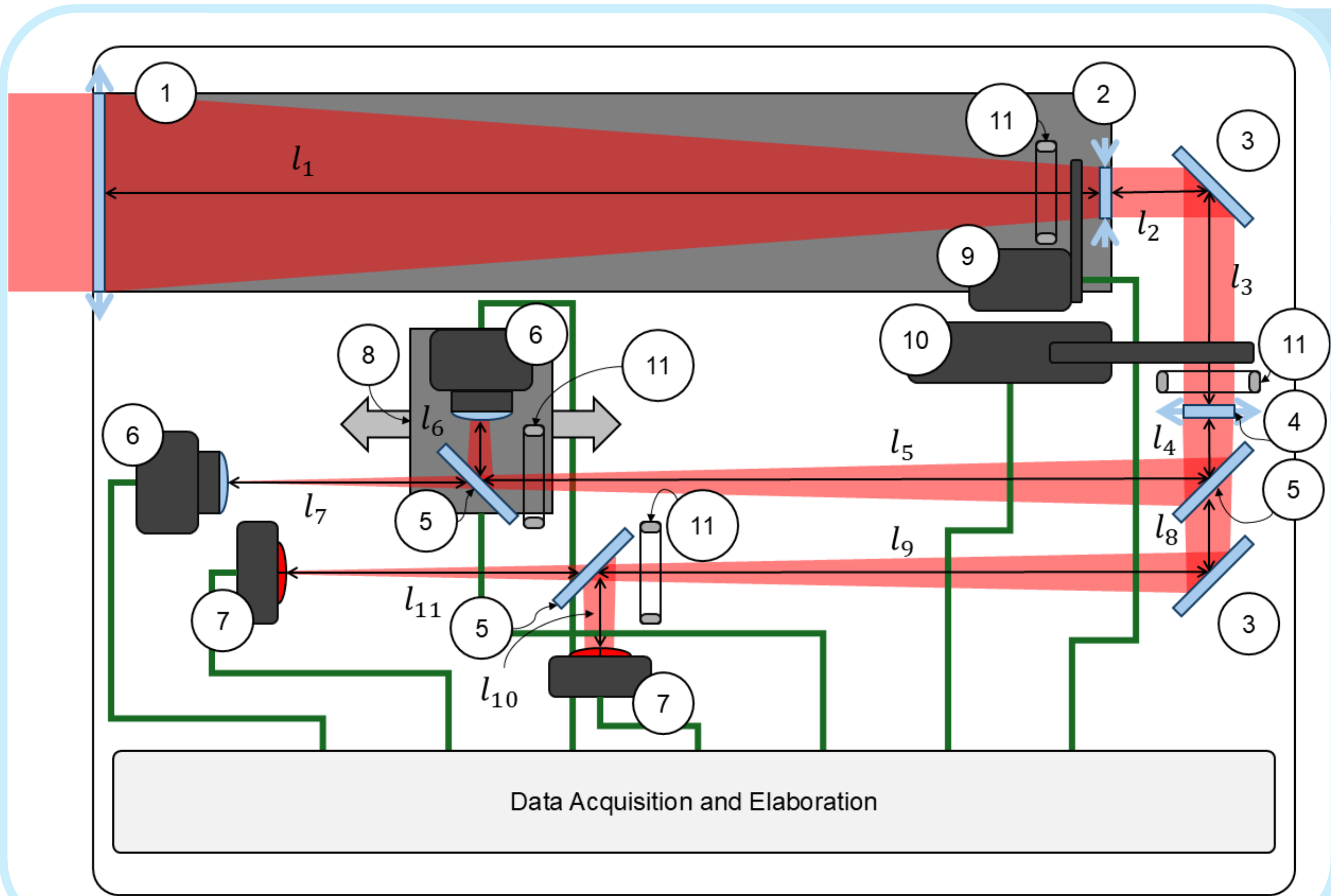
LPA – STAR

Laser-Plasma Acceleration – STabilization for Radiotherapy

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Laser-plasma accelerators (LPAs) can generate high-quality electron beams in compact, fully optical setups, with promising applications in radiotherapy. However, beam stability is limited by laser pointing fluctuations at various timescales, caused by thermal drifts, air currents, and mechanical vibrations. These instabilities affect the reproducibility of electron generation and must be mitigated to meet clinical standards, which require dose uncertainties below 5–7% and spatial accuracy in the millimeter range.

We propose a **compact, vacuum-compatible system for active beam stabilization based on diagnostics** performed on a replica of the main laser beam. Installed near the laser-plasma interaction point, the system enables real-time measurement of laser position and direction at focus using cameras and Position-Sensitive Detectors (PSDs). Fast-processing electronics drive feedback to the final steering mirrors, suppressing high-frequency jitter. This approach aims to **enhance LPA stability and support its transition toward medical applications**.



Measurement and Diagnostic Setup

Diagnostics are used to control

1. Converging lens L1, 4", F=600 mm
2. Diverging lens L2, 1", F=100 mm
3. Mirror Ø2"
4. Converging lens L4, 1", F=500 mm
5. Beam splitter 50:50, Ø2", 350 - 1100 nm, t = 8.0 mm
6. CCD camera
7. PSD
8. Linear movement
9. Shutter for laser beam
10. Motorised ND filters
11. Adjustable pinholes

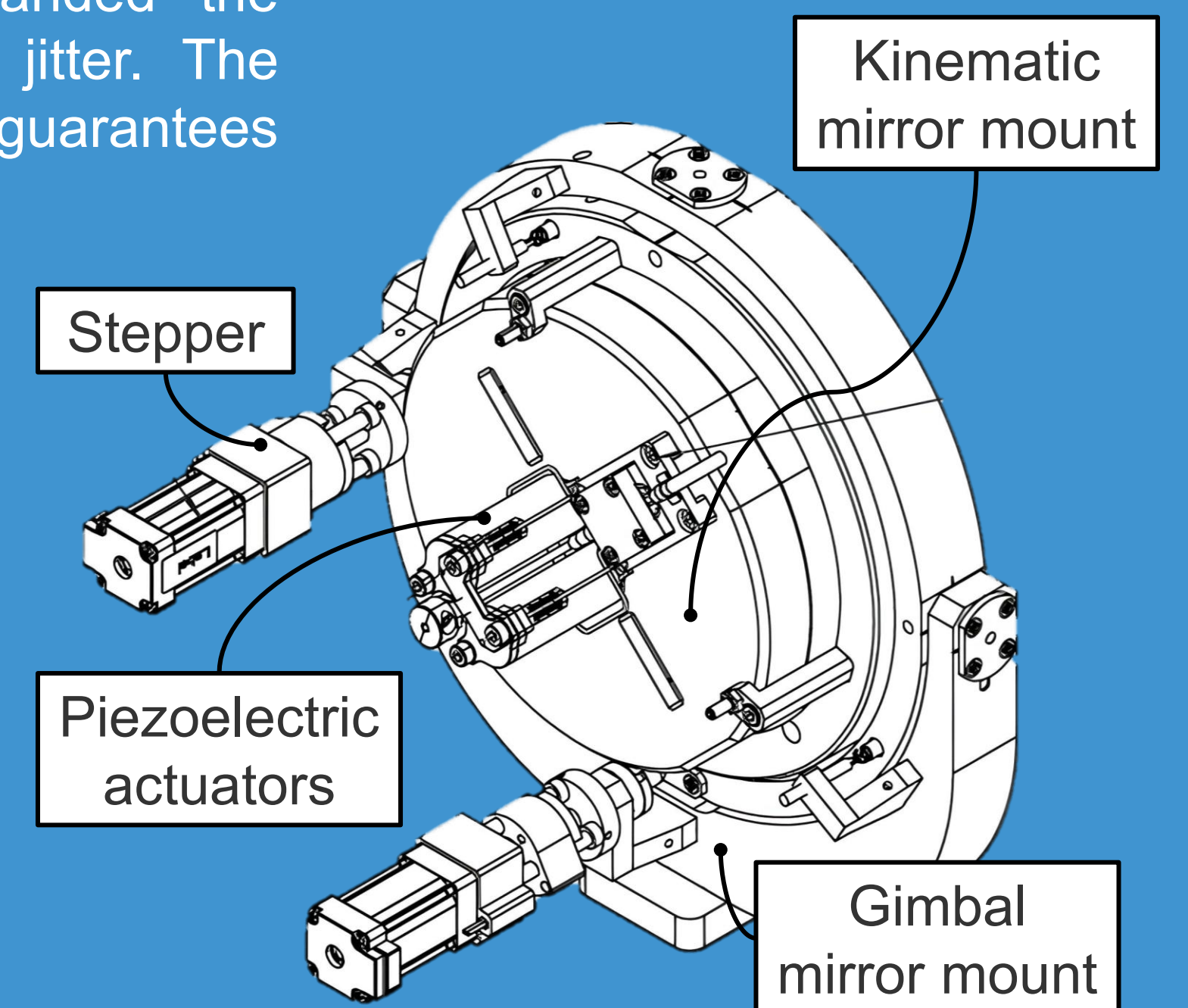
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High-Frequency Motorized Mirror Mount

The **measurements** from the laser diagnostic are used to **control 2 motorized mirror mounts** and stabilize the laser pointing jitter. The mirror mounts are composed by:

- a **"slow dynamic"** part, composed by a gimbal mirror mount motorized via **stepper motors**, to be used for the low-frequency alignment with long range excursion
- a **"fast dynamic"** part, composed by a frame-in-frame solution, with a **piezo-actuated kinematic mirror mount** fitted into the gimbal. To the piezoelectric actuator is demanded the stabilization of the high-frequency jitter. The custom mount near the mirror axis guarantees the needed angular range.

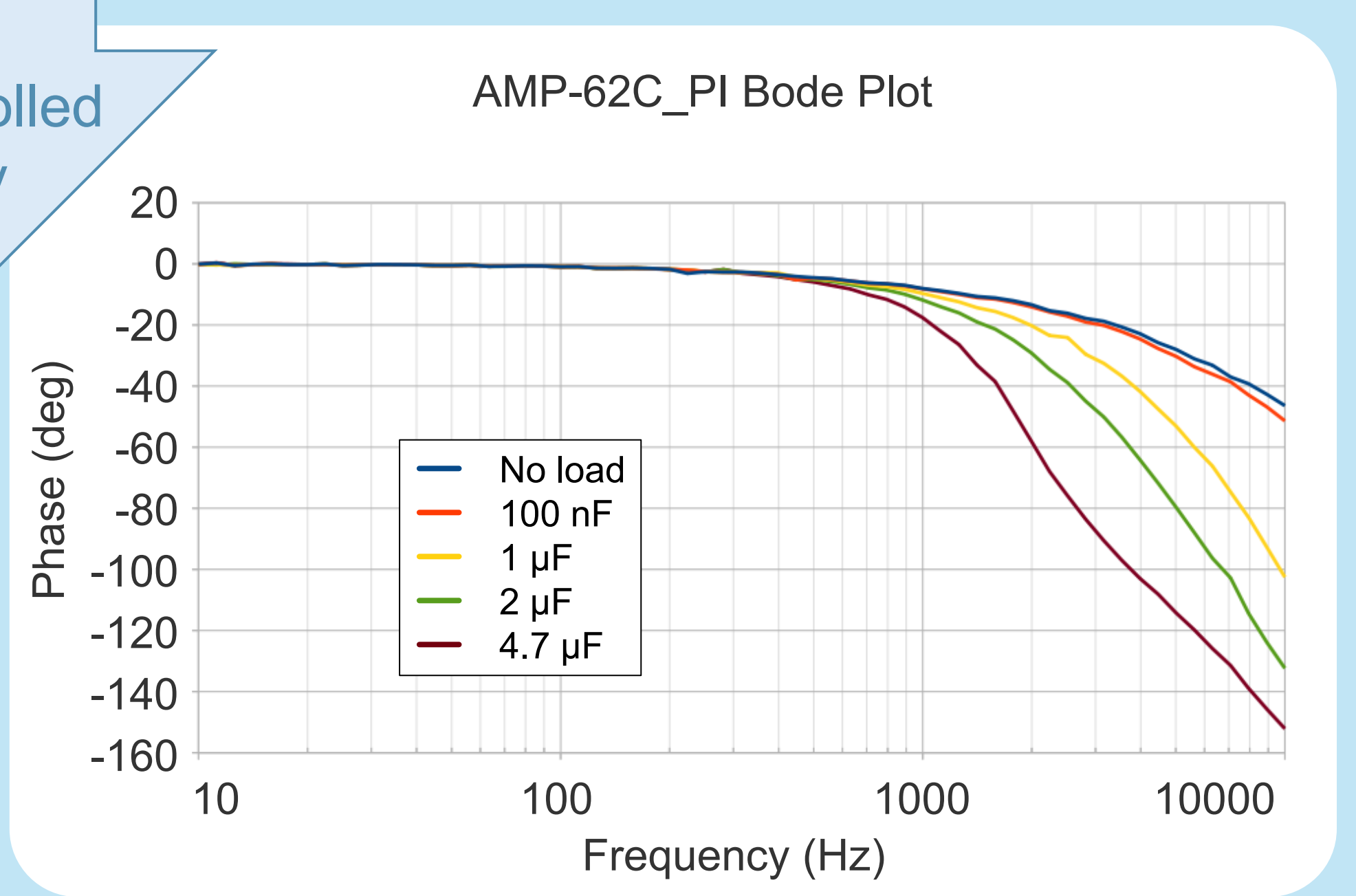
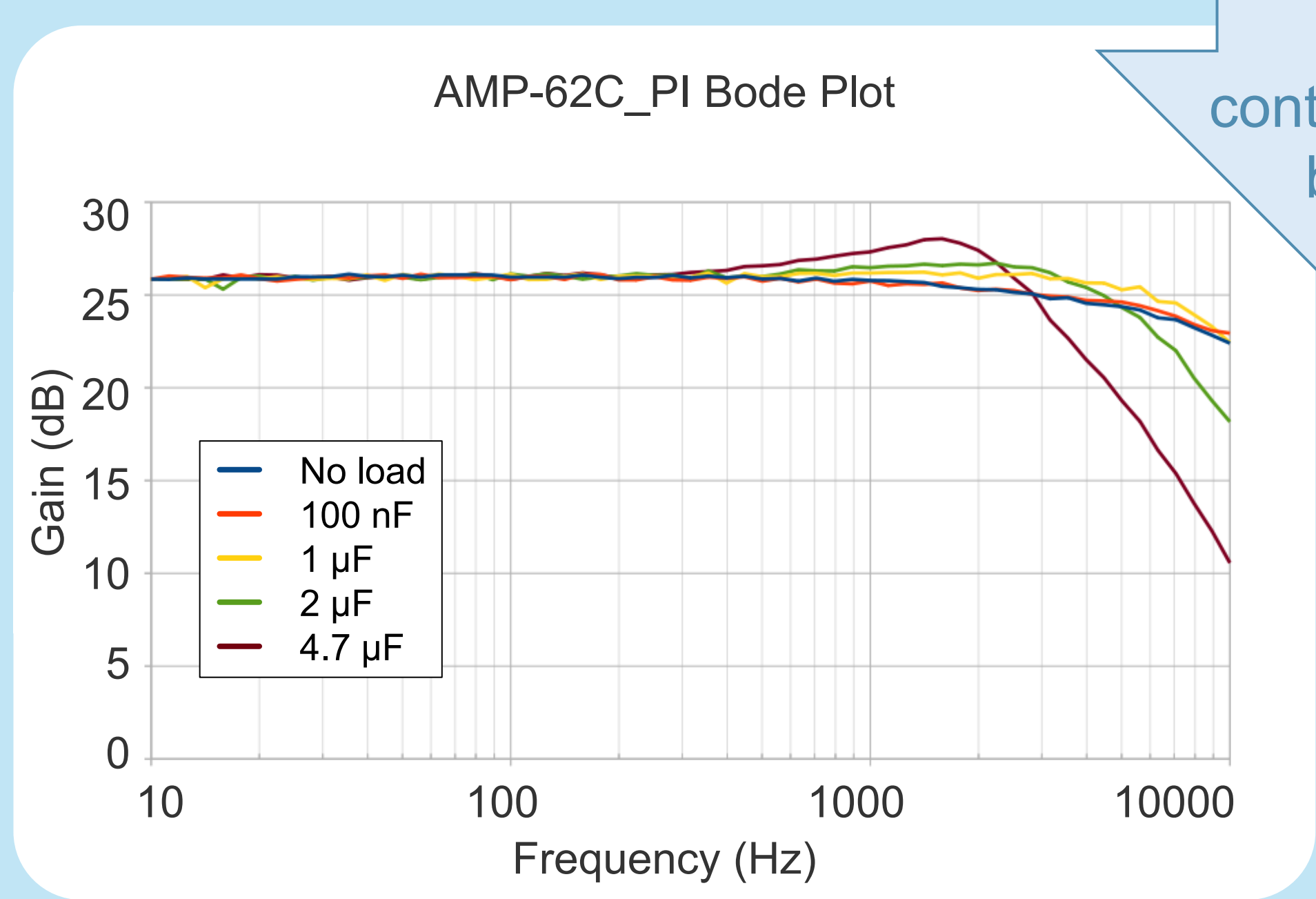


Is fitted in

Vacuum Chamber

Vacuum chamber designed to operate at 10-6 mbar. The system is designed to be vacuum compatible and to be easily implemented in the *Intense Laser Irradiation Laboratory (ILIL)*. The chamber hosts the vacuum measurement devices and an optical table for the laser diagnostic setup.

HV Amplifier



High voltage amplifier for driving piezoelectric actuators. The capacity, greater than 4 µF, requires specific measures in the design of the AC drive board for frequencies above Hertz, respecting the operating voltage (-20V to +100V). The circuit contains a 'booster' stage that automatically intervenes when the current demand increases. This allows frequencies above 100s Hertz to be reached. Two heat sinks have been installed, one for the standard transistors and one for the Booster transistors (the latter cooled by a fan).

The **Bode diagrams** show stable frequency behavior in terms of both amplitude and phase up to frequencies well above the design frequency, using loads with capacities even higher than that of the chosen piezoelectric actuator.