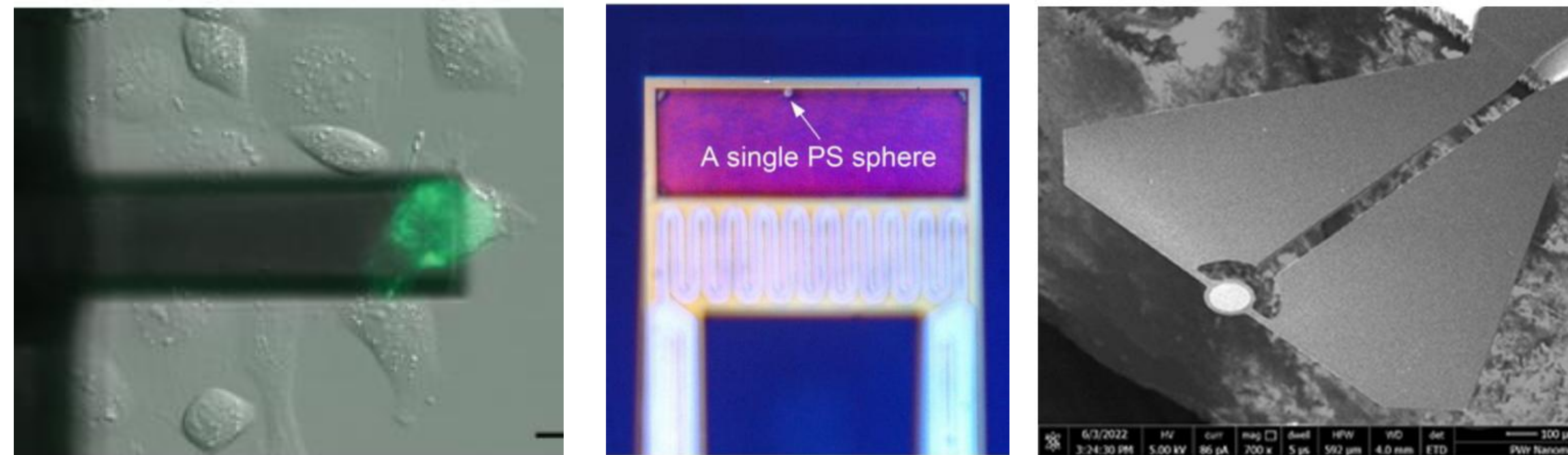


Introduction

- As the demand for applications in fundamental research grows, measurement technologies utilizing micro-cantilever probes has expanded to include mass measurement of cell growth, analysis of chemical properties and light pressure measurement.



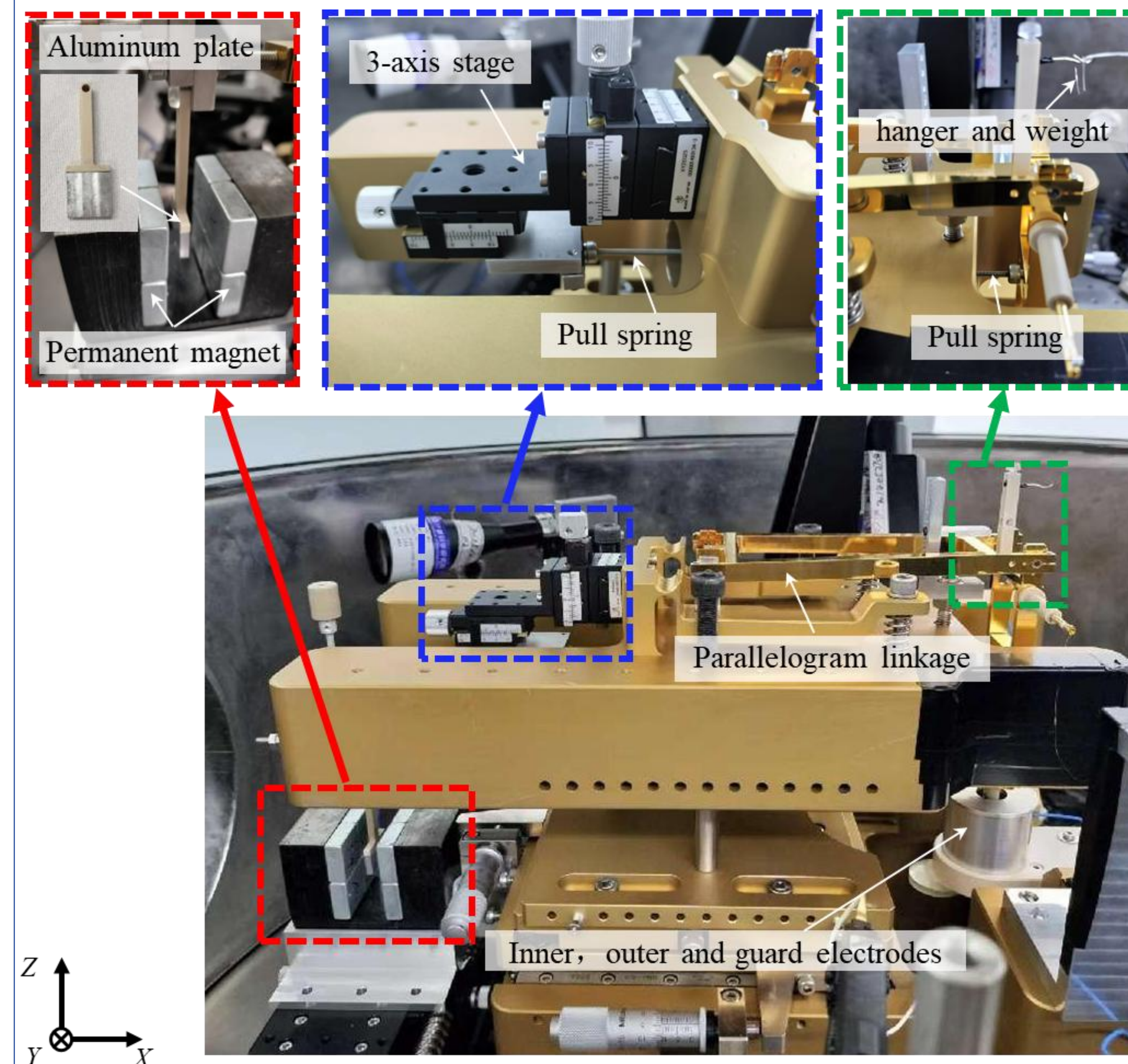
Cell mass measurement

Chemical analysis

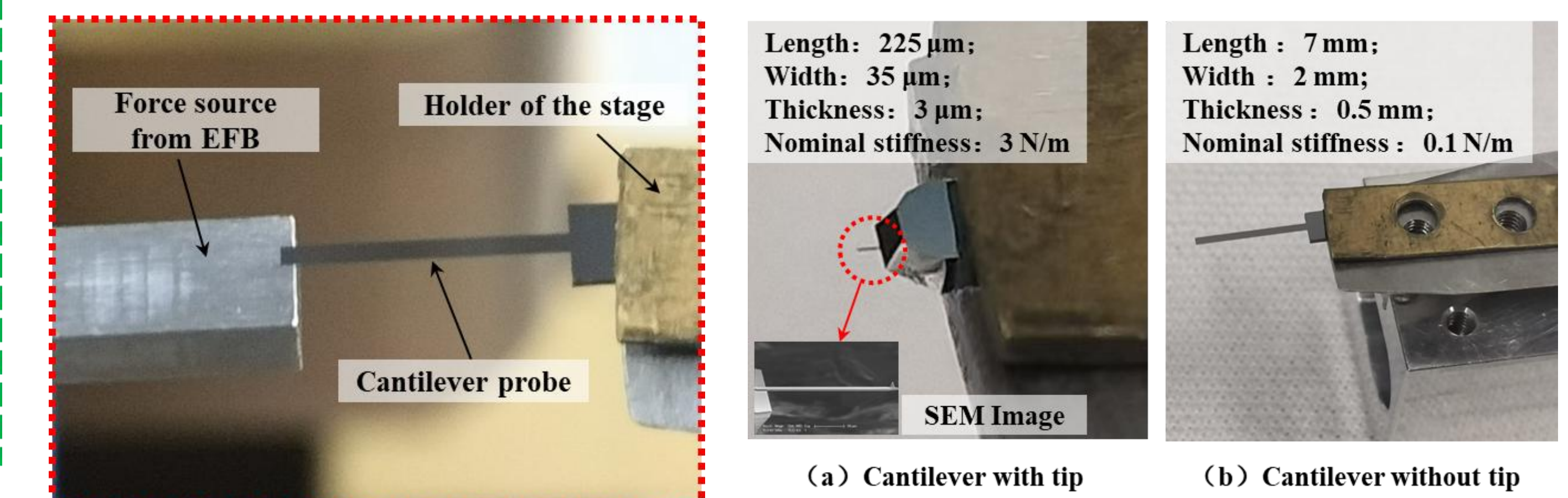
Light pressure measurement

- The National Institute of Metrology (NIM) has developed an electrostatic force balance (EFB) apparatus for measuring small force at micro-newton levels.
- The force generated by the EFB can serve as a force source in the contact method for calibrating micro-cantilever stiffness.

Experimental Setup



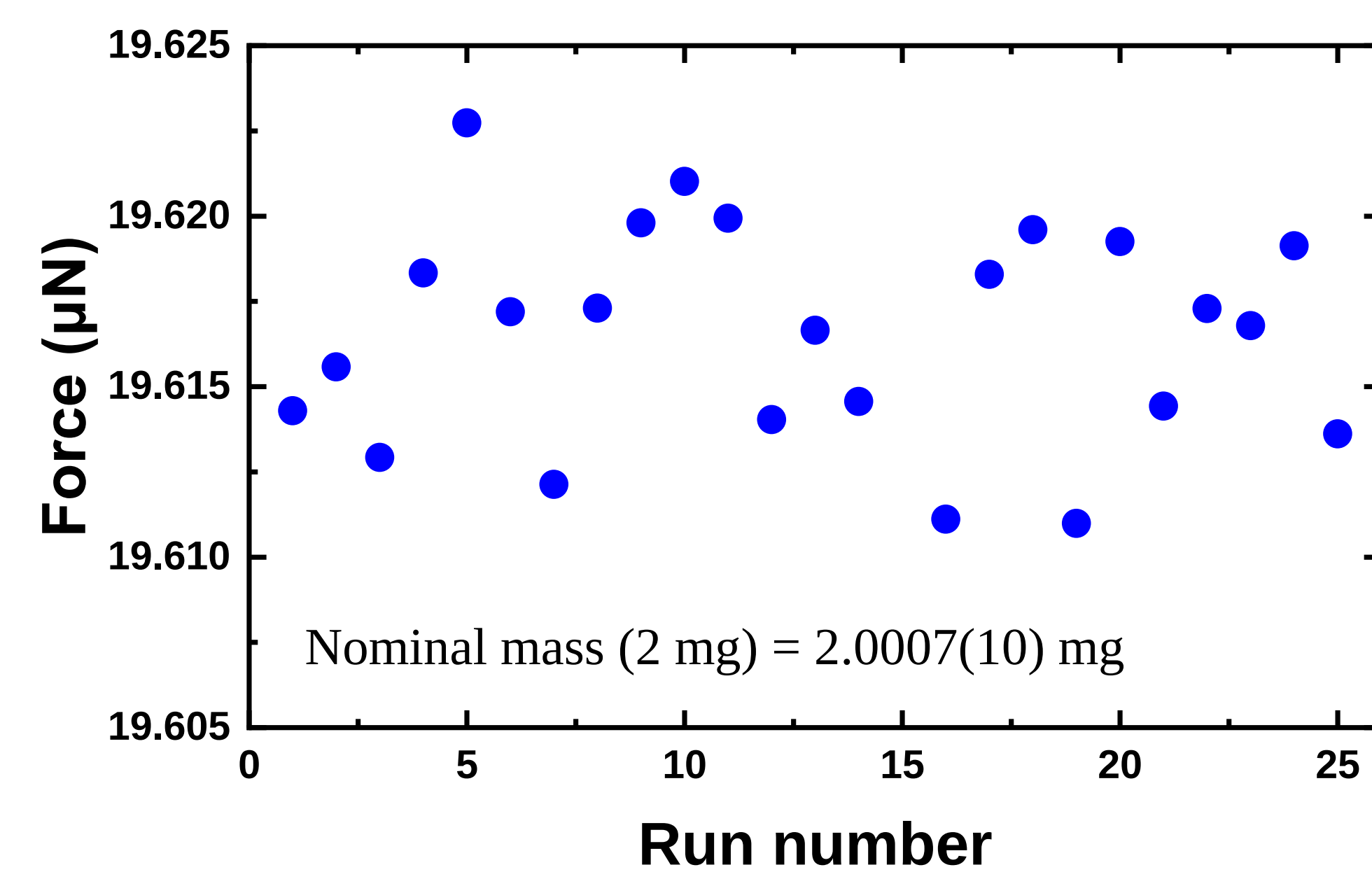
Photographs of the EFB being developed at NIM



Photographs of the cantilever calibration setup and two types of cantilever probe

- A laser interferometer (RLD10-X3-DI, Renishaw) was utilized to measure the displacement of two electrodes in the vertical direction;
- The capacitance between two electrodes was measured by a capacitance bridge (AH2700A, Andeen-Hagerling) in the capacitance gradient mode;
- A stable voltage source (Source Meter2410, Keithley) was applied on capacitor to generate the electrostatic force in the force measurement mode;
- The electrostatic force generated by the EFB as a force source to actuate the deflection of the cantilever probe;
- Cantilever with and without tip were calibrated using the developed device.

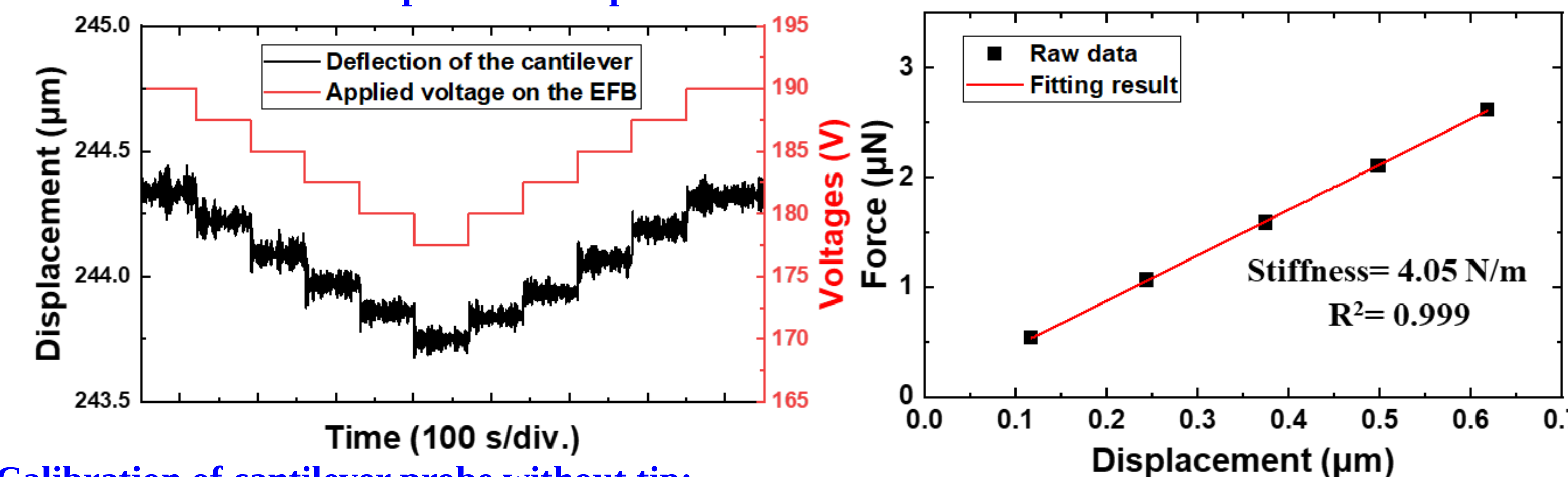
Reproducibility of EFB Apparatus



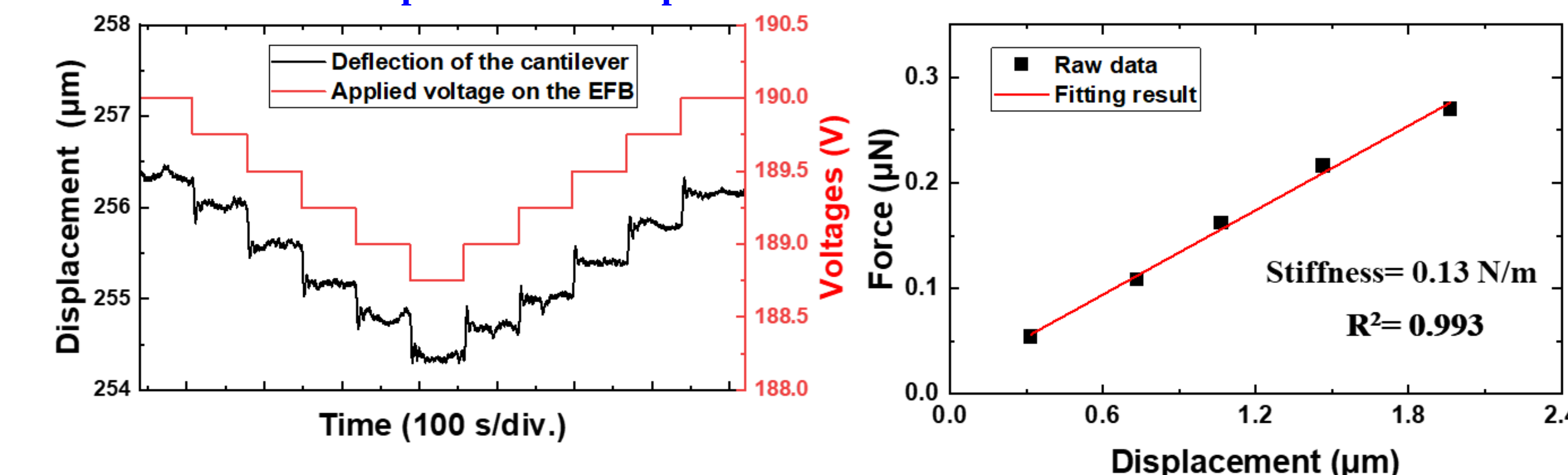
- A 2 mg wire weight with class E1 was measured 25 times by the developed EFB at NIM;
- The average capacitance gradient is evaluated to be 1.139109×10^{-3} pF/μm;
- The gravitational force of the artefact is evaluated to be $19.61667 \mu\text{N}$ with a standard deviation of $3.6 \times 10^{-3} \mu\text{N}$;

Calibration of the Cantilever Probe

Calibration of cantilever probe with tip:



Calibration of cantilever probe without tip:



- Stiffness of the cantilever probes before correction are evaluated to be 4.05 N/m and 0.13 N/m with a standard deviation of 0.114 and 1.16×10^{-3} N/m, respectively.

Conclusion

- An electrostatic force balance (EFB) is being developed for the measurement of traceable small forces at NIM;
- The procedures for capacitance gradient calibration and force measurement were demonstrated by determining the gravitational force of a 2 mg wire weight using the developed EFB;
- The Stiffness of the cantilever probes in the range of 0.13 N/m to 4.05 N/m can be successfully calibrated based on the EFB apparatus;
- The stiffness calibration method effectively improves traceability for micro-cantilever measurements of small mass or force at the picoNewton level;
- In the future, an optical method for accurately adjusting the displacement and posture of the micro-cantilever will be developed to reduce the uncertainty components of the orientation introduced in the stiffness calibration;
- In the future, uncertainty in the evaluation of the stiffness of the cantilever probe will also be analyzed.