

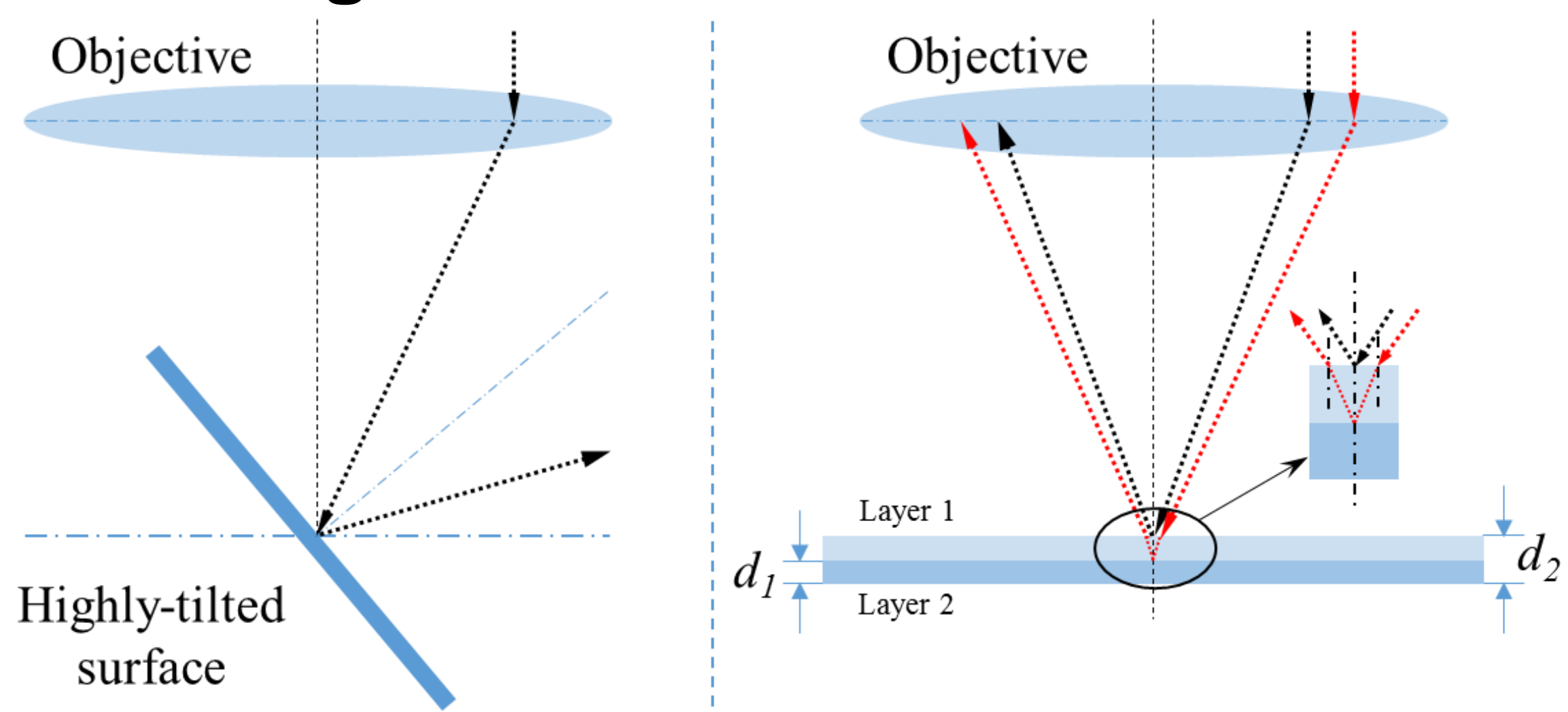
Imaging beyond the fundamental slope limit in surface metrology using fluorophore-aided scattering microscopy

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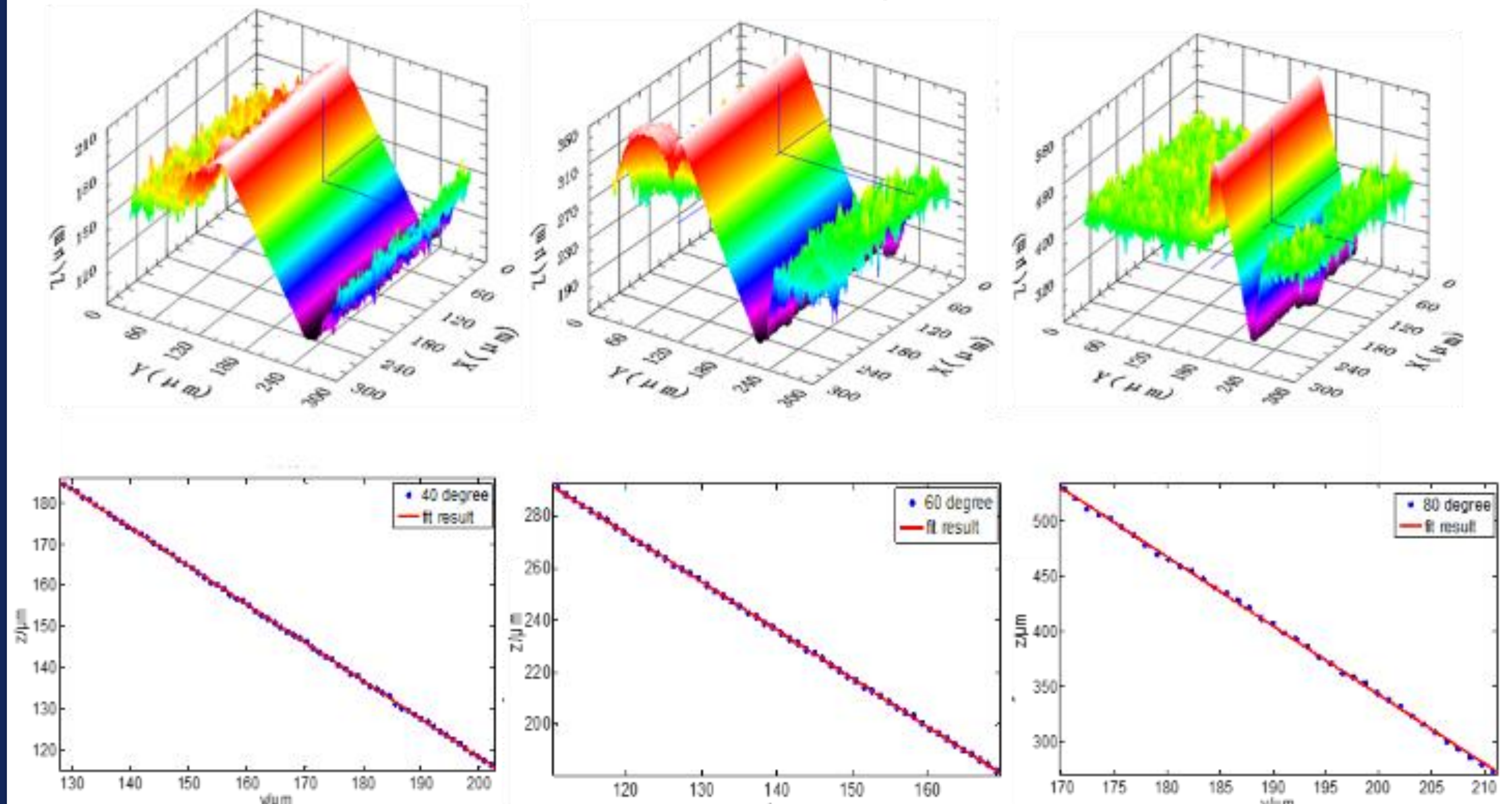
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Limitation of traditional confocal microscopes for measuring smooth surfaces



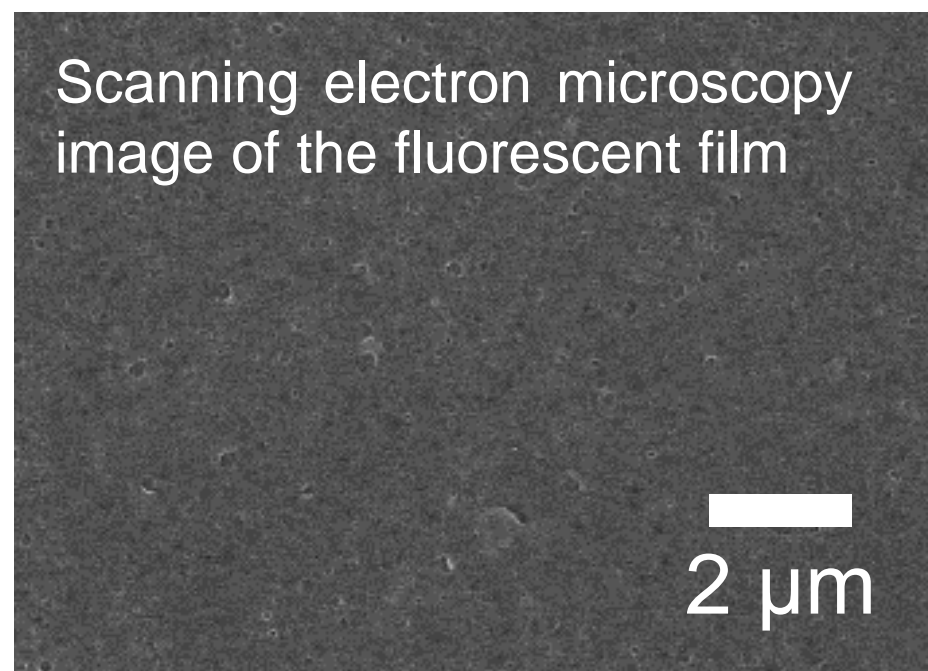
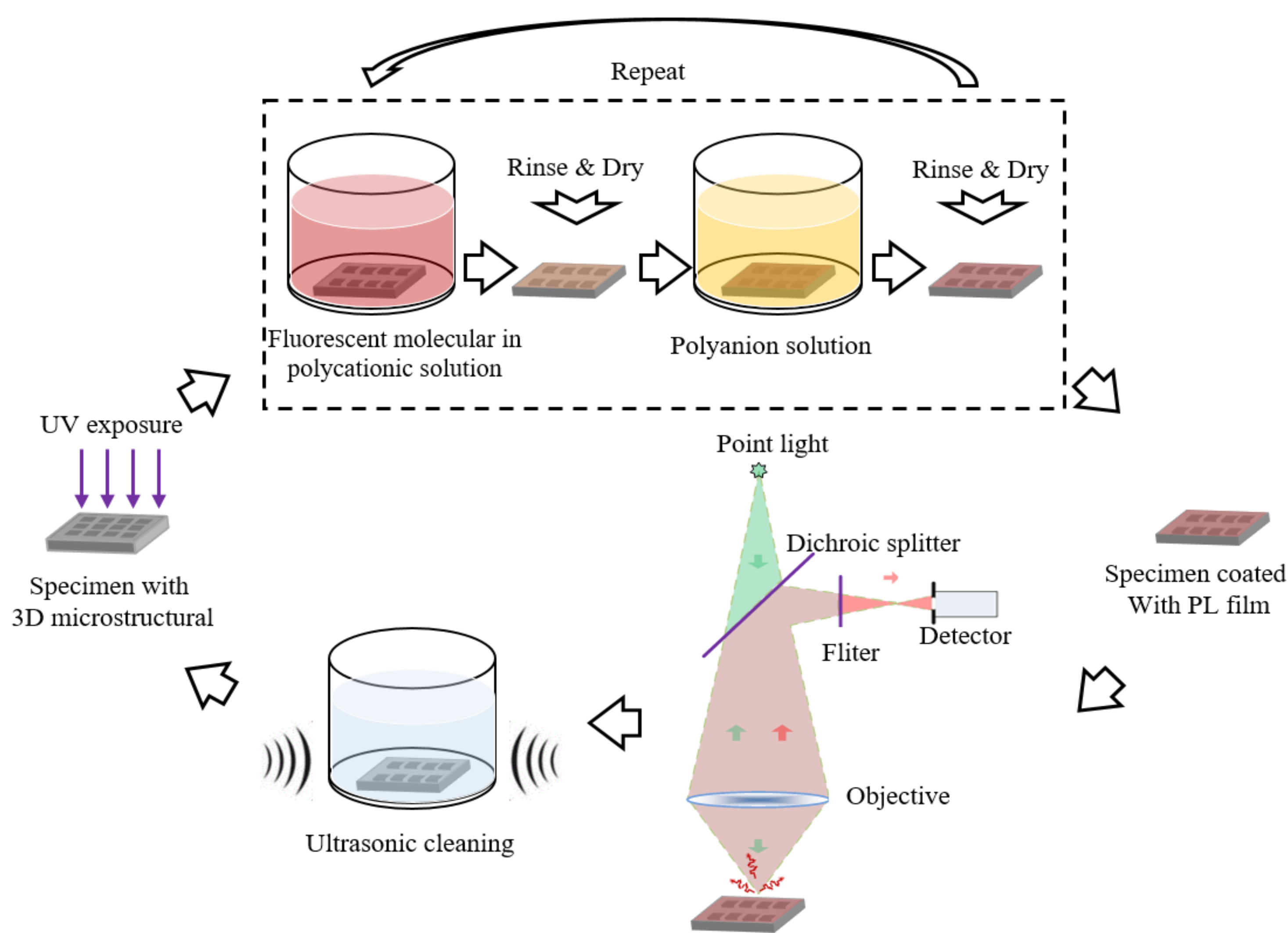
- Light reflected by the tilted surface cannot be sufficiently collected by the objective due to the limited numerical aperture (NA), resulting in low signal-to-noise ratio and detectability, and large measurement uncertainty
- When measuring the topography of a semi-transparent surface, the reflection or scattering from the subsurface causes significant error

Enhanced measurement of high slopes



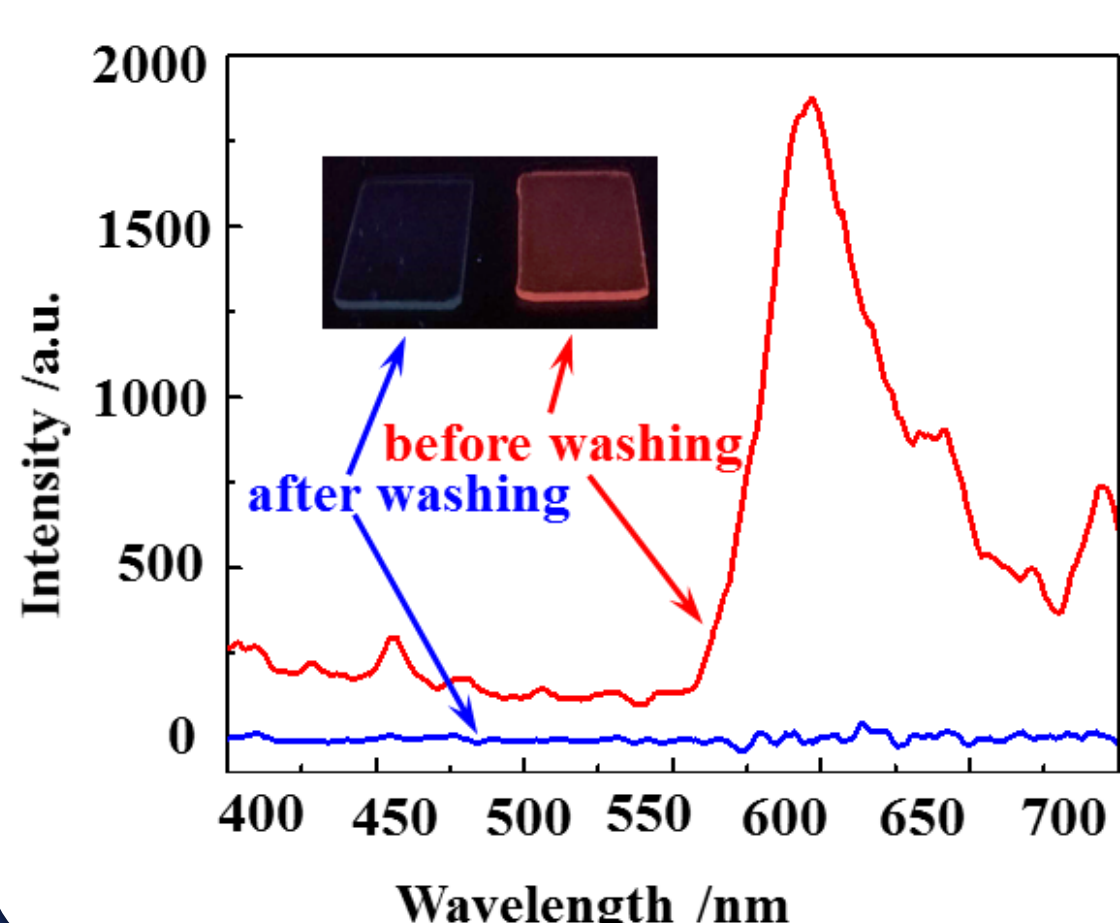
- All the slope angles are beyond the theoretical slope limit of traditional confocal microscopy, which is $\pm 24^\circ$ for measuring smooth surface with NA 0.4
- FAM measures slope angle up to 80° with NA 0.4

Fluorophore-aided scattering microscopy (FAM)



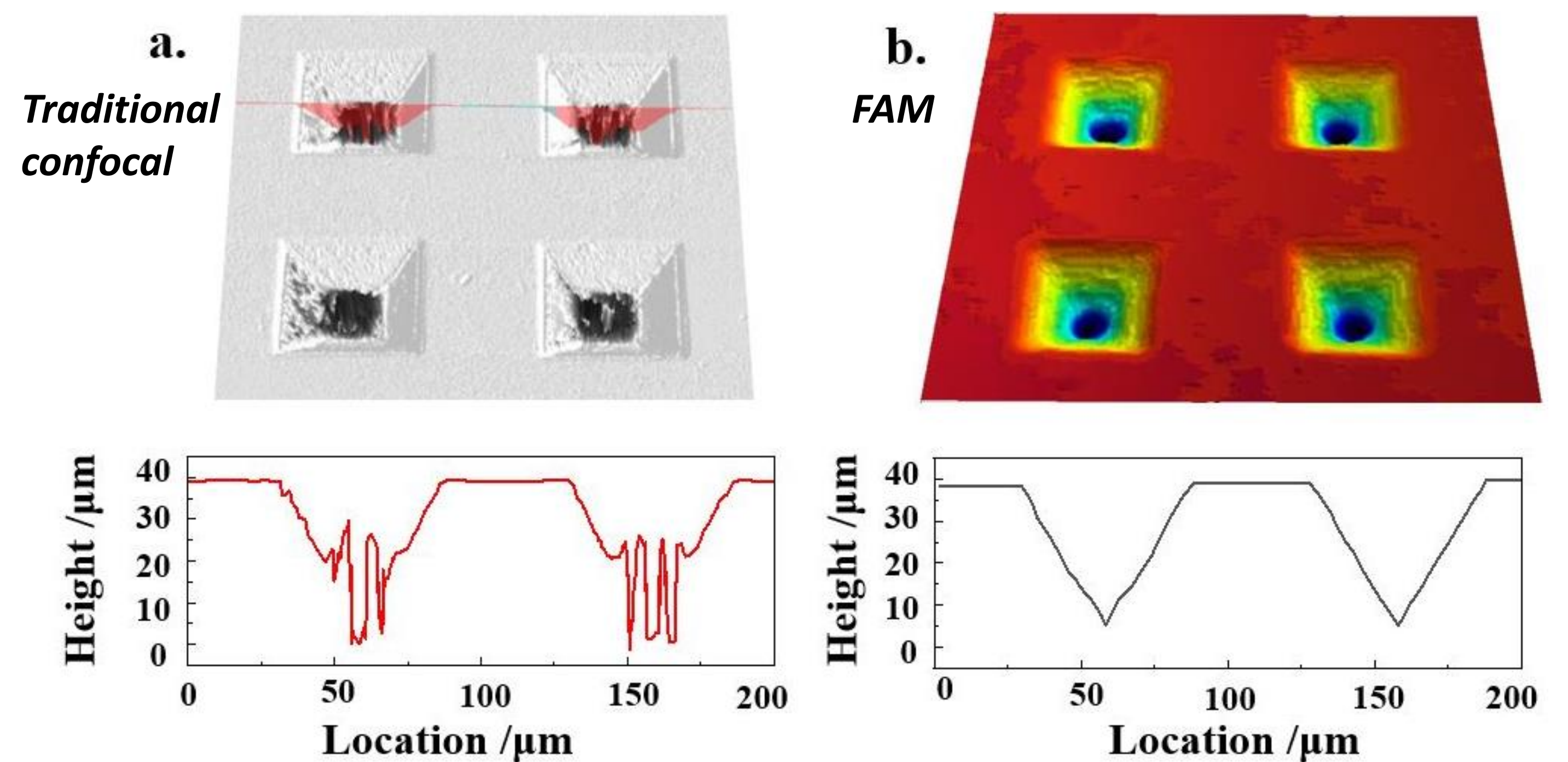
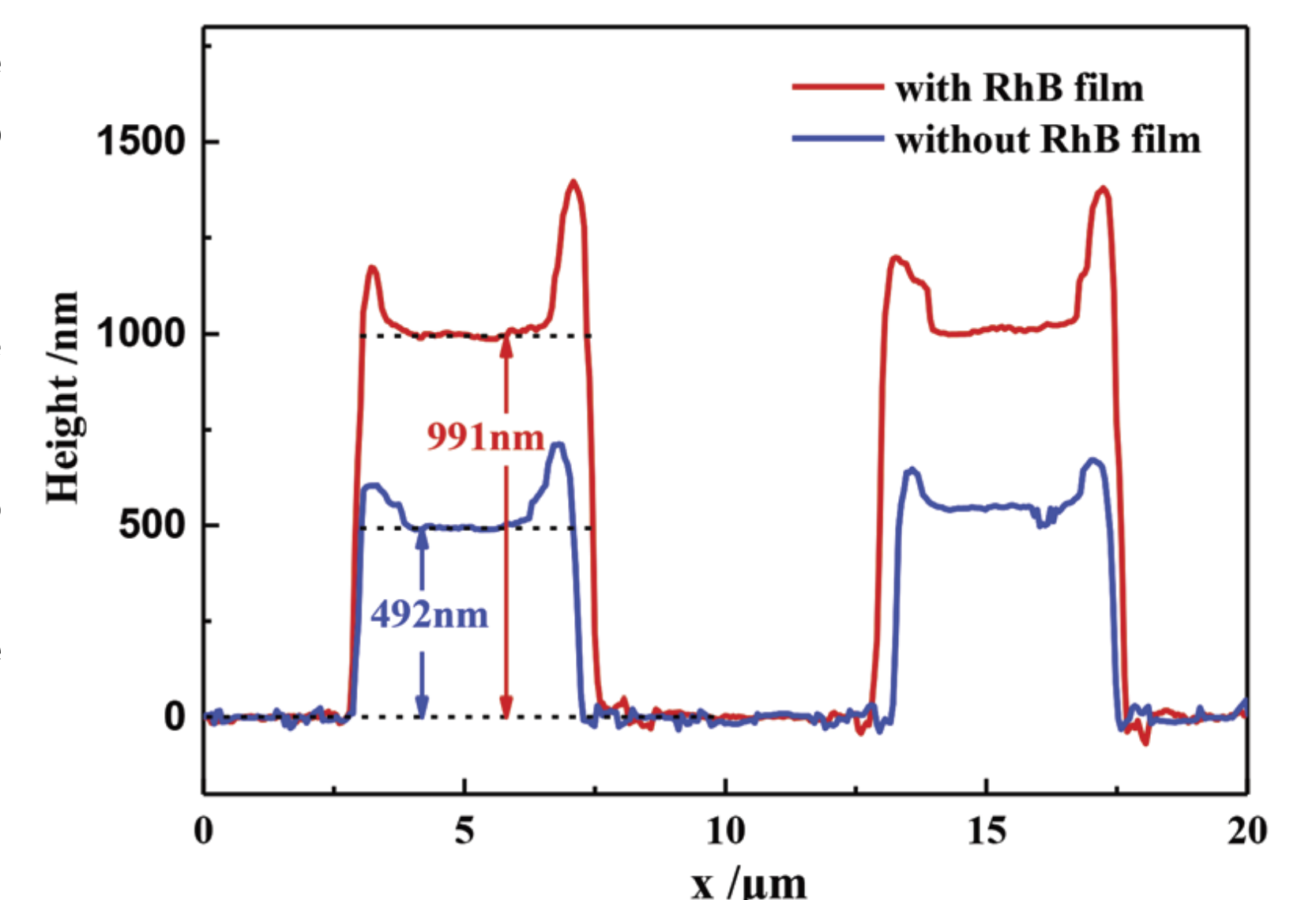
- 'Label' the surface by depositing an easily-removable fluorescent film (Rhodamine B) with a thickness of tens of nanometres on to the specimen
- The layer-by-layer self-assembly technique based on electrostatic adsorption is used to generate uniform coating of the fluorescent film on the surface
- A fluorescent confocal microscope is used to measure the surface topography. The detected signal is significantly enhanced with the aid of fluorescence due to the scattering by the surface now being more isotropic

Reference: Li L, Liu J, Liu Y, Liu C, Zhang H, You X, Gu K, Wang Y and Tan J. *Nanoscale* 10 9484 (2018)



Enhanced measurement accuracy

- The FAM provides a more accurate measurement of a step height artefact (nominal height 1 μm) compared to a traditional confocal microscope (both have NA 0.4)
- Surface topography of a deep vee-shaped groove specimen (with slope angle of 57.4°) can be accurately measured using an objective with NA 0.4



Future work

- Explore the feasibility of other organic or inorganic fluorophore materials, since biocompatibility is not required for engineering surfaces
- Improve the measurement capability for freeform surfaces with high slopes by using the developed FAM technique