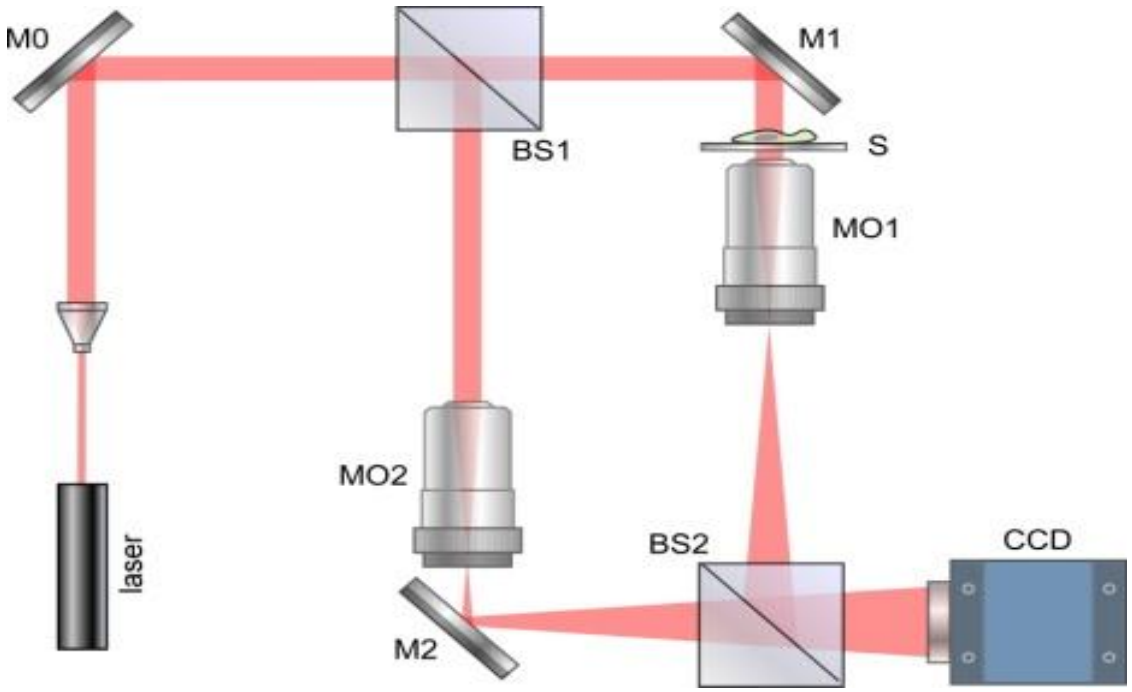
Measurement of the traction force of biological cells by digital holography

- Introduction
- DHM setup and methods
- Experiment results and discussions
- Conclusion

➢Introduction

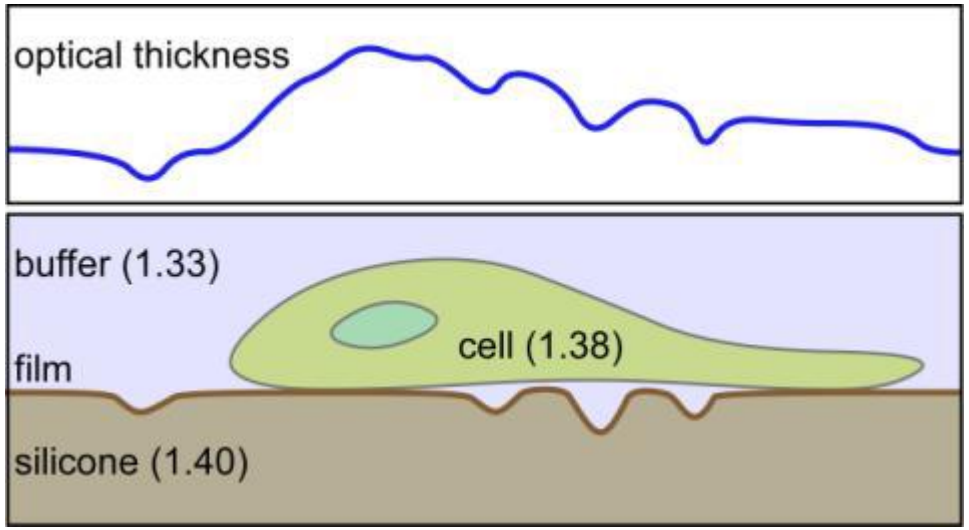
- Quantitative phase microscopy by digital holography (DH-QPM) was used to study the wrinkling of a silicone rubber film by fibroblasts.
- Surface deformation and the cellular traction force have been measured from phase profiles in a direct and straightforward manner.

➢DHM setup



M’s: mirrors; BS’s: beam splitters; MO’s: microscope objectives; S: sample object

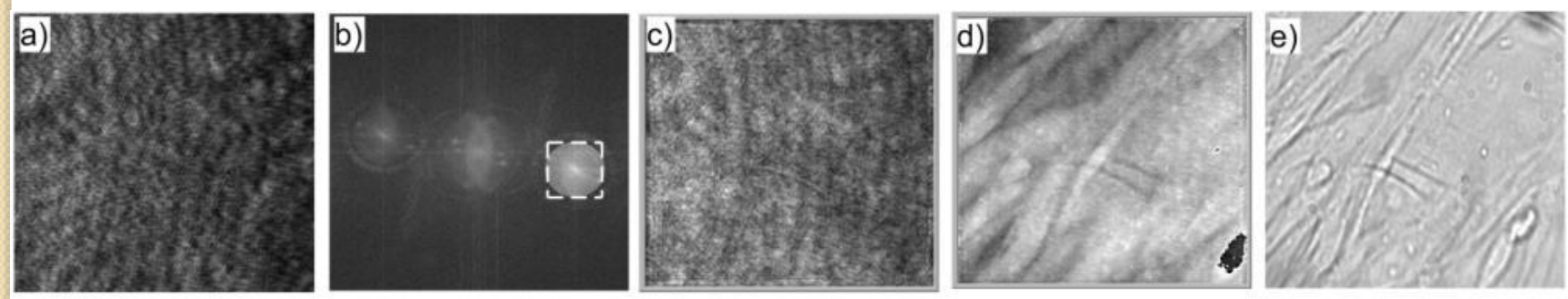
➢Cells-substratum samples



Schematic of the cell-substrate sample (lower) and the corresponding optical thickness profile (upper).

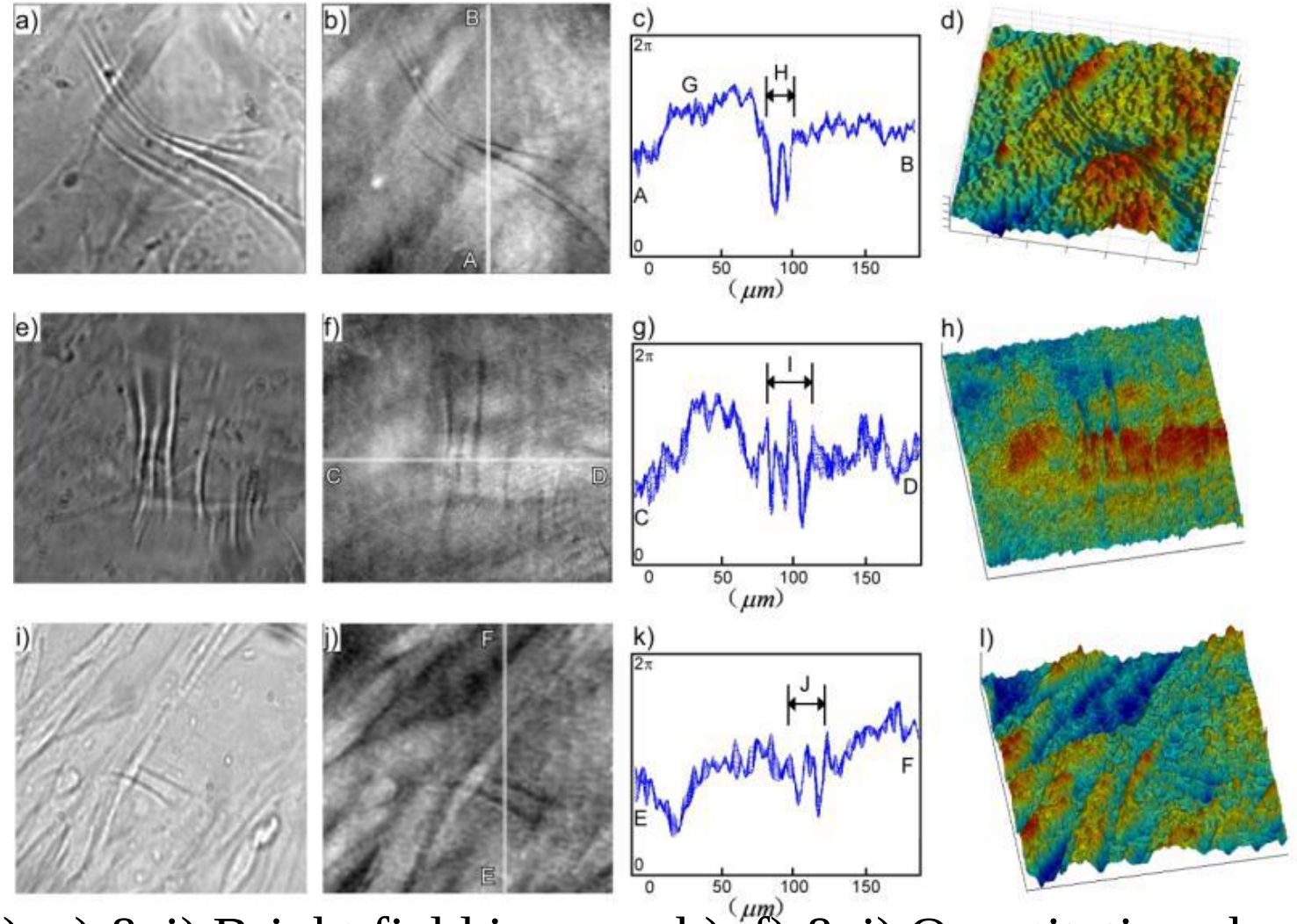
➢Results and Discussions

DHM analysis



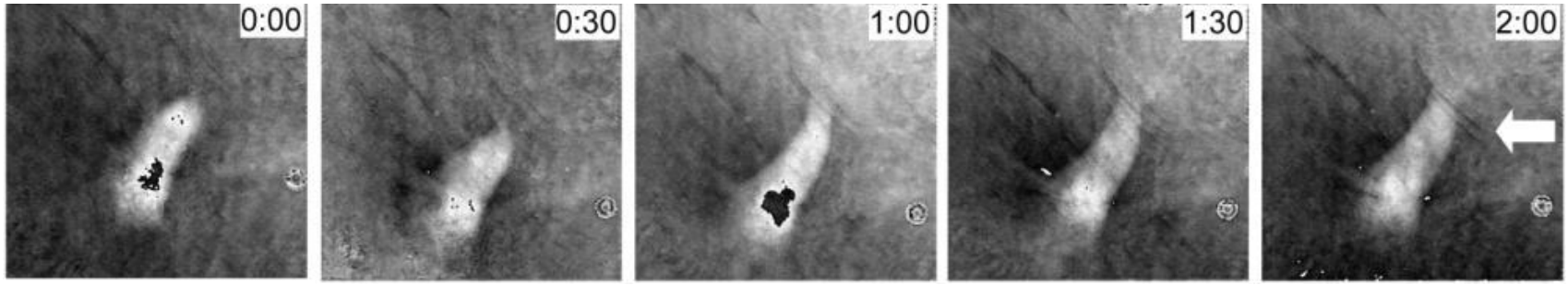
DHM analysis of fibroblasts wrinkling the silicone rubber film. The field of view is 190×176 μm^2 with 800×742 pixels.
a) Hologram; b) Angular spectrum; c) Amplitude image; d) Quantitative phase image; e) Bright field image.

Examples of results



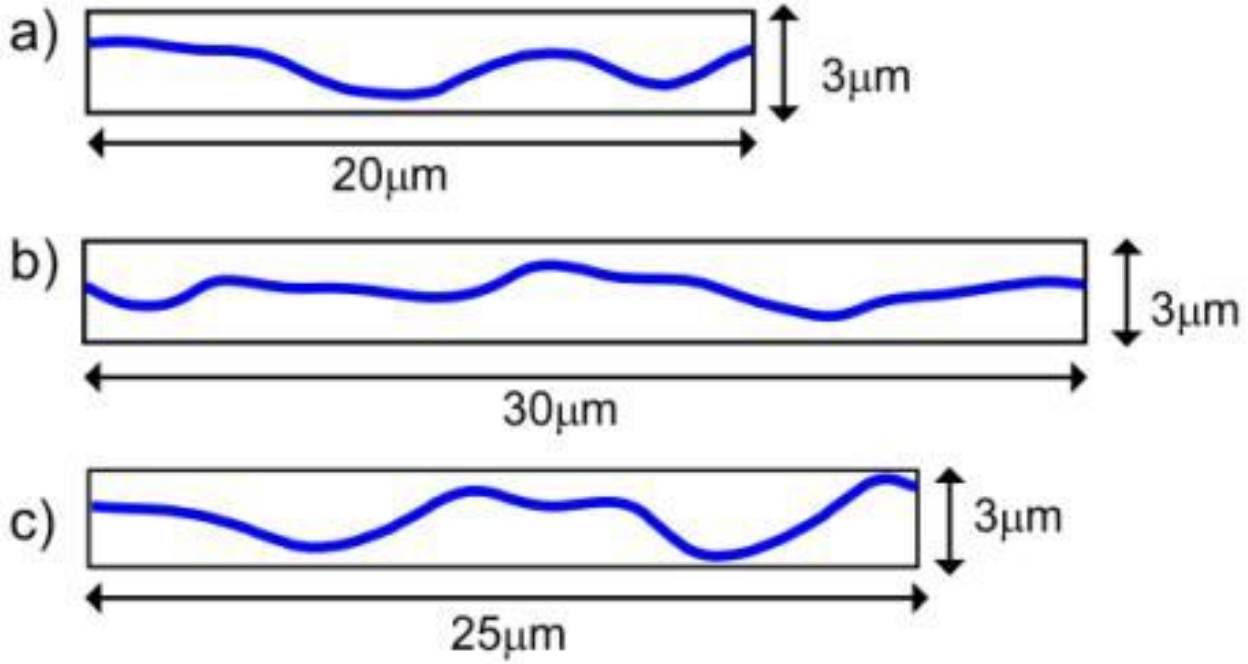
a), e) & i) Bright field images; b), f) & j) Quantitative phase images; c), g) & k) Cross-sections of phase profiles along highlighted lines AB in b), CD in f) and EF in j); d), h) & l) Pseudo-color 3-D rendering of phase images b), f) & j).

Phase movie of fibroblasts wrinkling the silicone rubber film



An excerpt of several frames from phase movie recordings of cells wrinkling a silicone rubber film.

Force estimation



- The amount of horizontal deformation = the total length of the graph - the horizontal distance.
- That is, a) 4.11 μm, b) 4.07μm, c) 3.94μm .
- The stiffness of the silicone rubber 0.001 dyn/μm , the traction force is ~4×10^{-3} dyn/cell

➢Conclusions

- The traction forces exerted by fibroblasts cultured on a silicone rubber substratum have been visualized as an elastic distortion and wrinkling by DH-QPM.
- The traction force has been measured as ~4×10^{-3} dyn/cell based on the degree of wrinkling determined from phase information.
- The basic principles of DH have been applied to quantitative imaging of wrinkles on silicone rubber due to cell adhesion and motility.
- The approach is sensitive to cellular forces and it can detect and quantify variations in force within the adhesion area of a cell over time.
- DH-QPM is shown to be an effective approach for measuring the traction forces of cells.