

Adaptive phase compensation for ultracompact confocal endomicroscopy

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Introduction

Background

- Explanation of confocal microscopy and its relevance to biomedical applications.
- Current methods used in microconfocal endoscopy and their drawbacks.

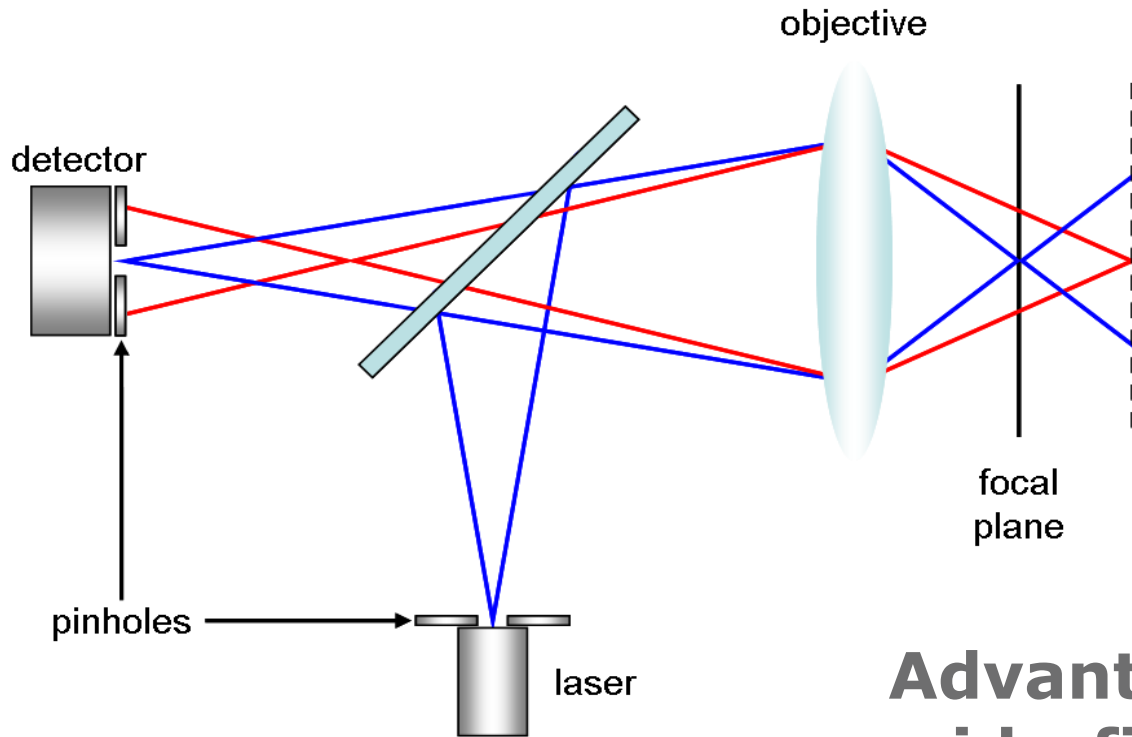
Proposed solution

- Theory and method of testing.

Experimental Results

- Proof of principle.

Confocal Microscopy

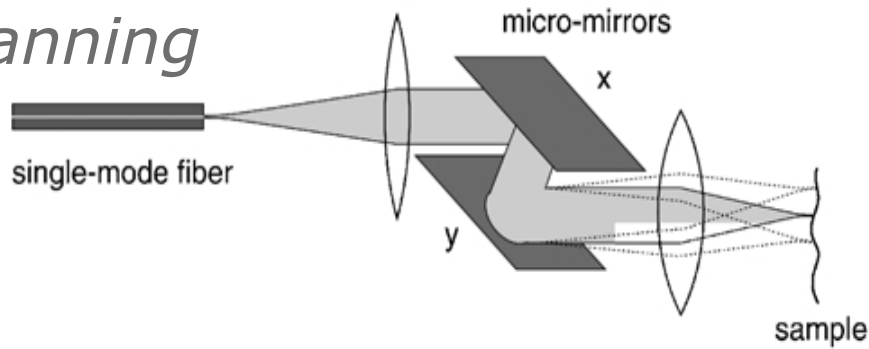


Advantages over wide-field microscopy:

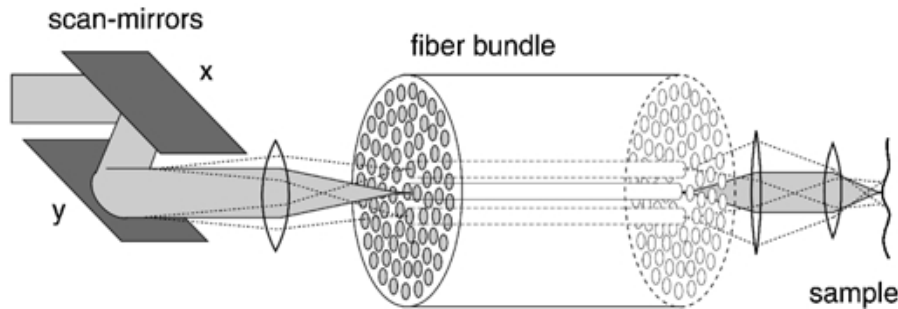
- *Improved resolution*
- *Improved SNR*
- *Optical sectioning*

Microconfocal Endoscopy

Distal Scanning

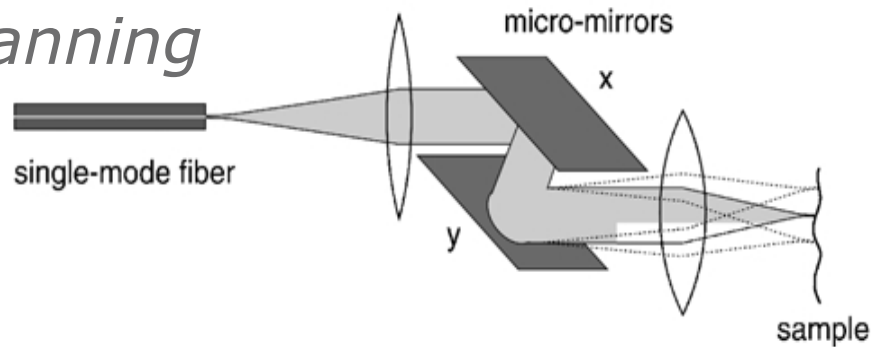


Proximal Scanning

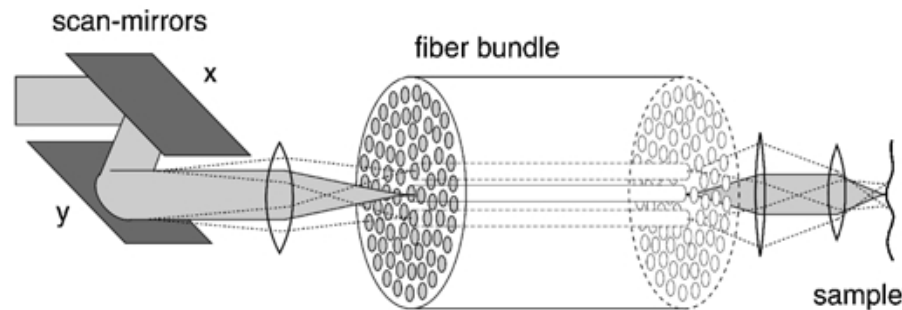


Microconfocal Endoscopy

Distal Scanning

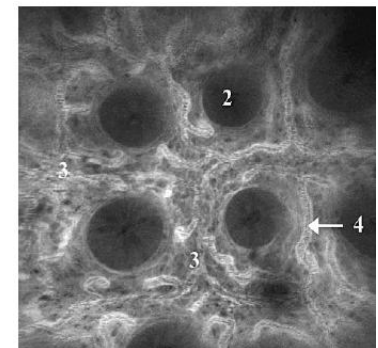


Proximal Scanning



Uses

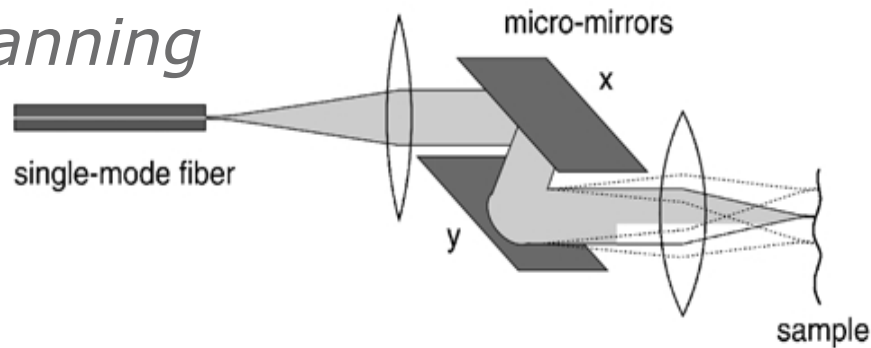
- *Small animal imaging in biomedical studies* ¹.
- *Use of flexible fibre optics means animals can behave freely.*
- *Used in clinical studies aimed at diagnosis of disease* ².



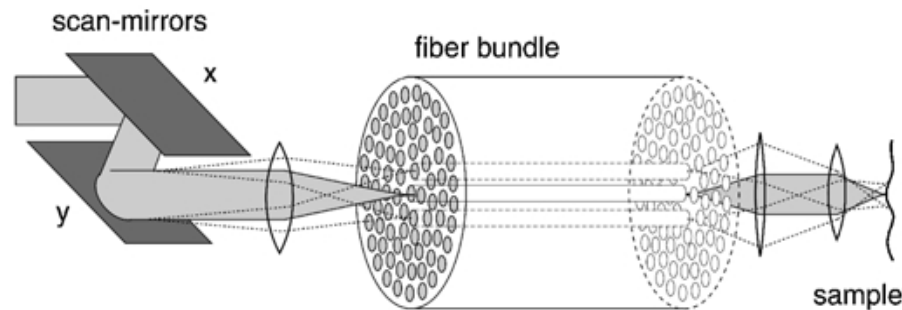
1. Flusberg et al., *Opt. Lett.* 30, 2272 (2005)
2. Polglase et al., *Gastrointest. Endosc.*, 62, 686 (2005)

Microconfocal Endoscopy

Distal Scanning



Proximal Scanning



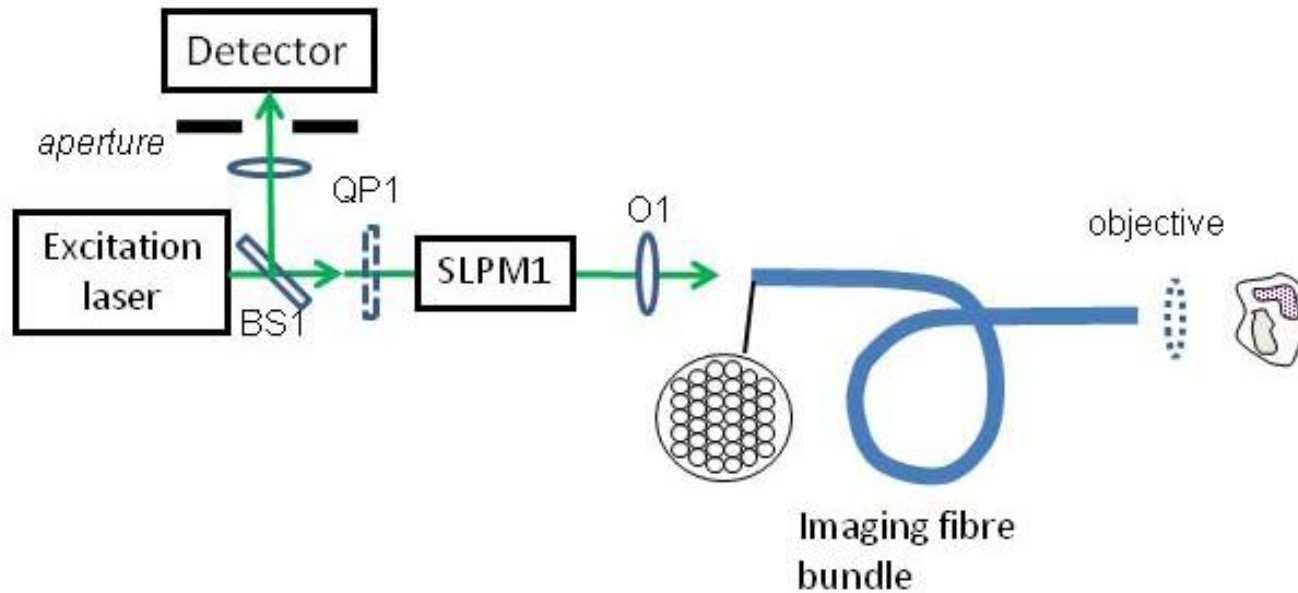
Problems

- *Minimum achievable size of the distal end is determined by the scanning system.*

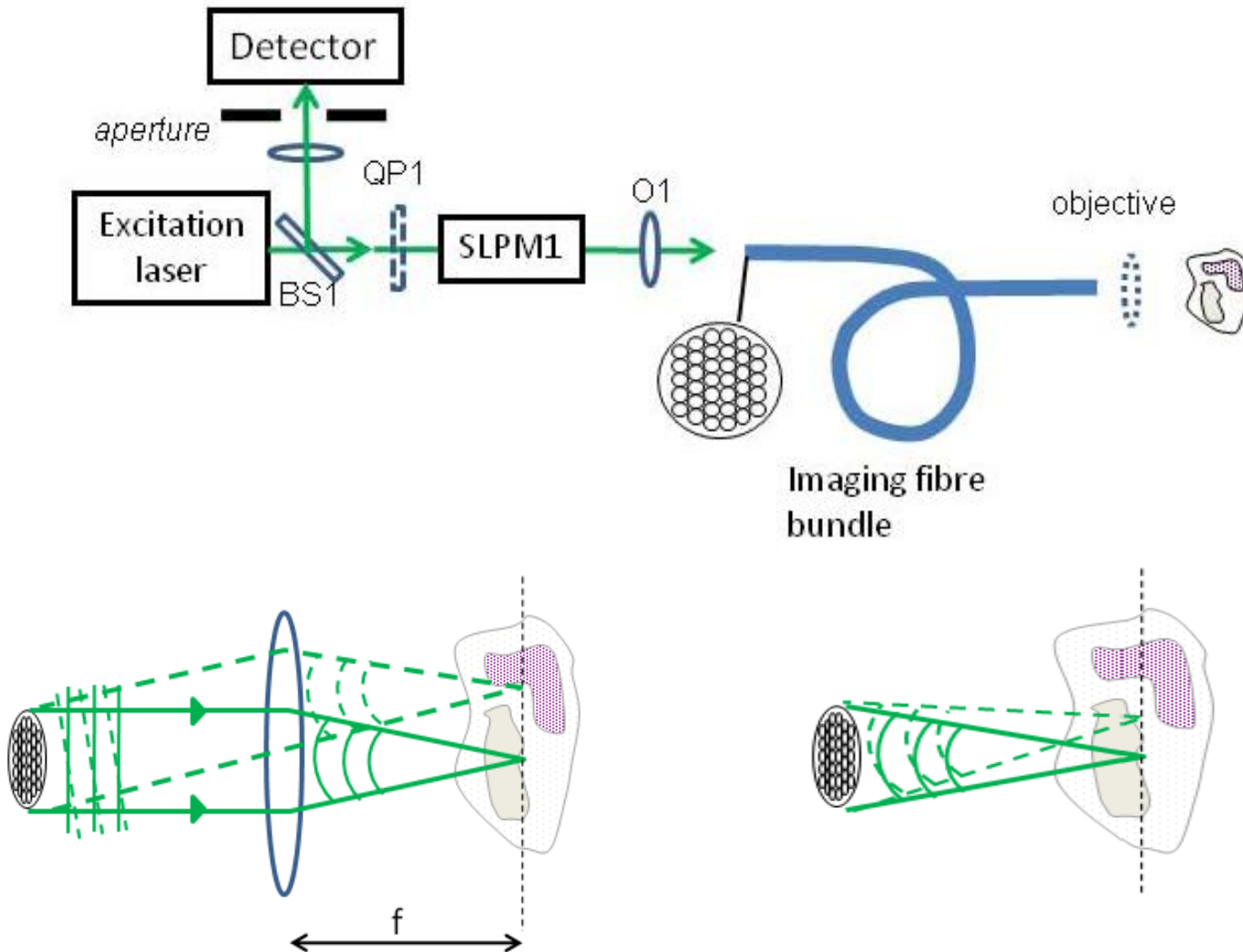
- *Limited number of pixels (i.e. fibre cores) and, hence, resolution elements.*

- *Undersampling due to space between fibre cores.*

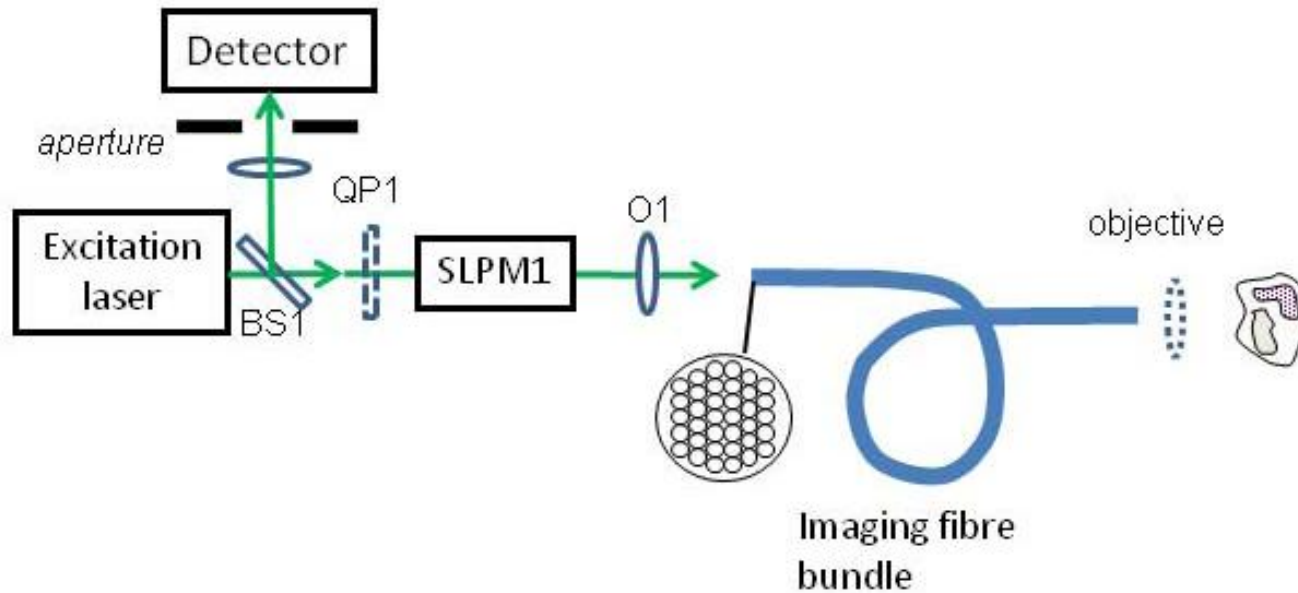
Novel Scanning Mechanism



Novel Scanning Mechanism



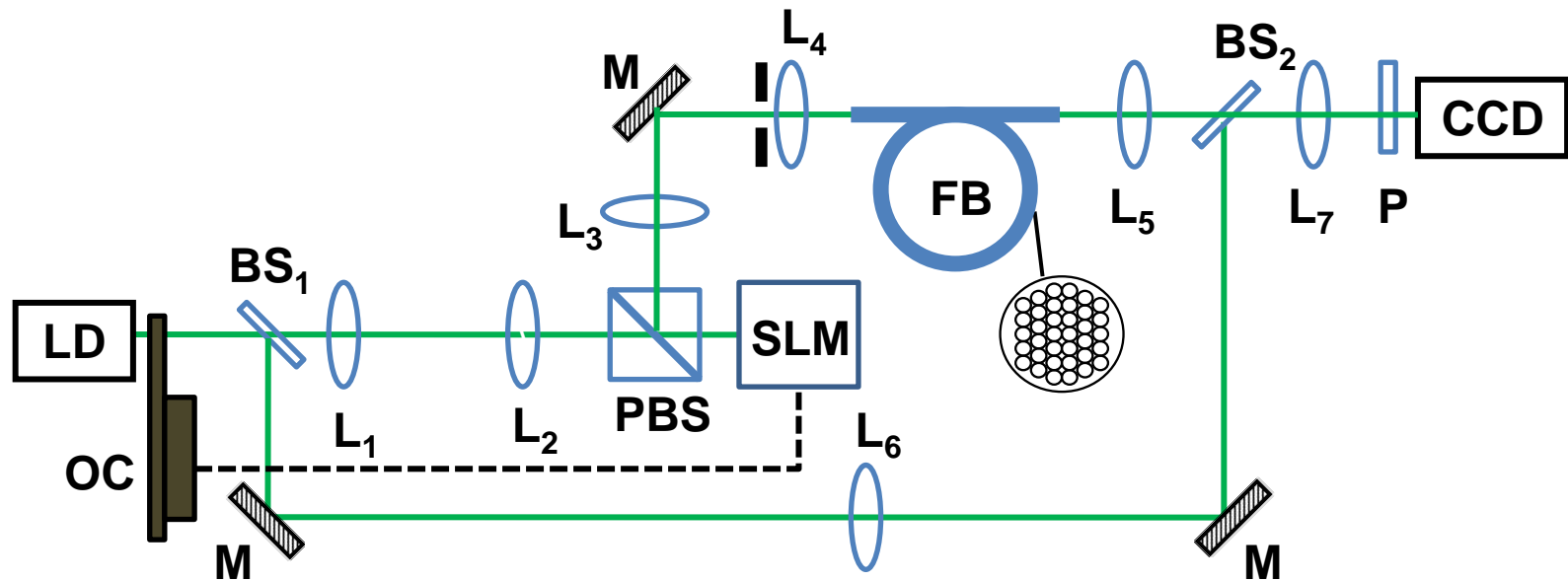
Novel Scanning Mechanism



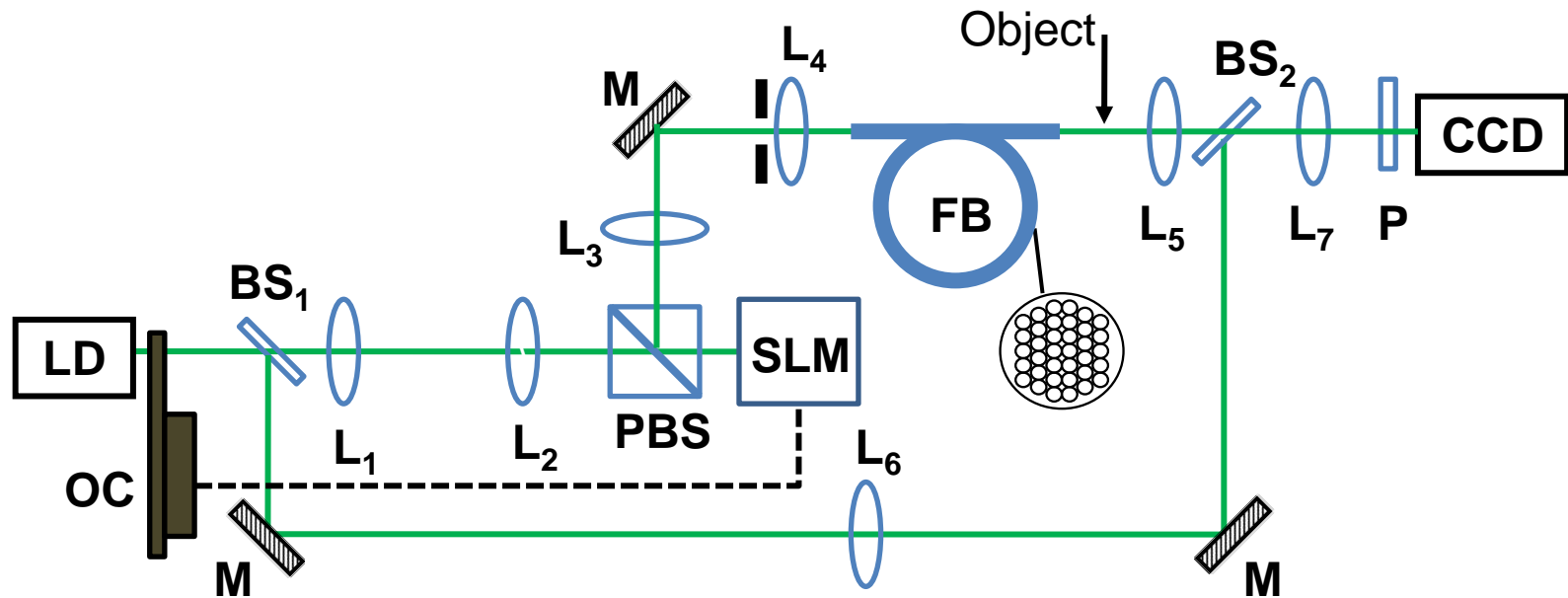
Advantages

- *Beam scanning without distal scanner or optics.*
- *Reduction in size of distal end means minimum endoscope size is limited only by size of fibre bundle.*
- *No more problems with undersampling as in the previous fibre bundle design.*
- *Possibility for adaptive correction of aberrations.*

Experimental Setup

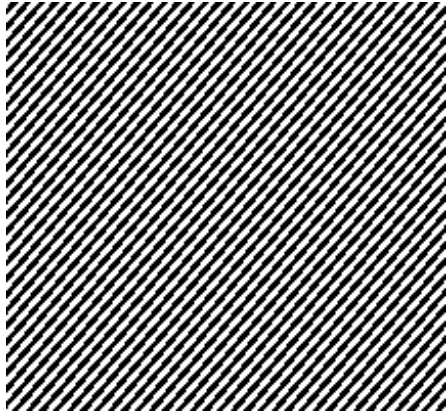


Experimental Setup

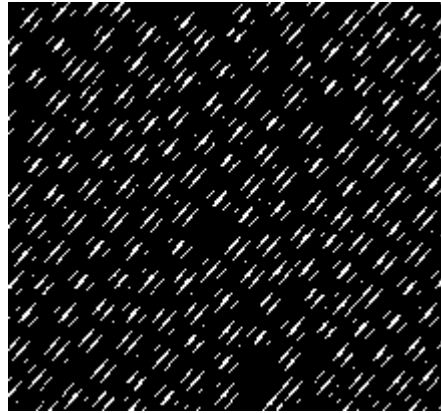


Hologram and Wavefront Generation

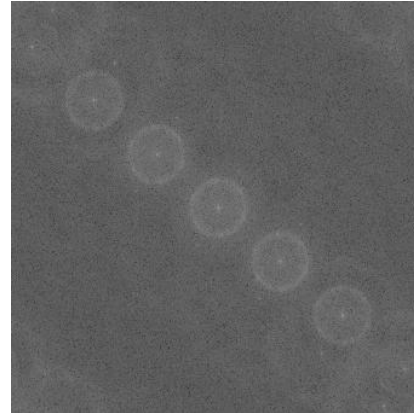
Plain Hologram



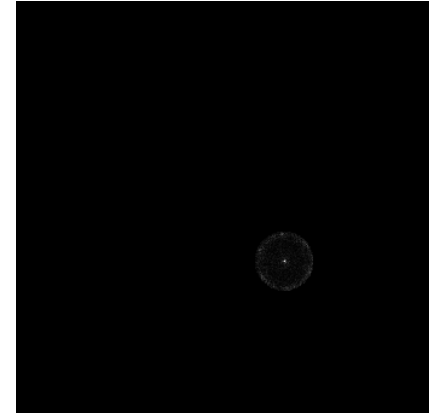
Amp. and Phase



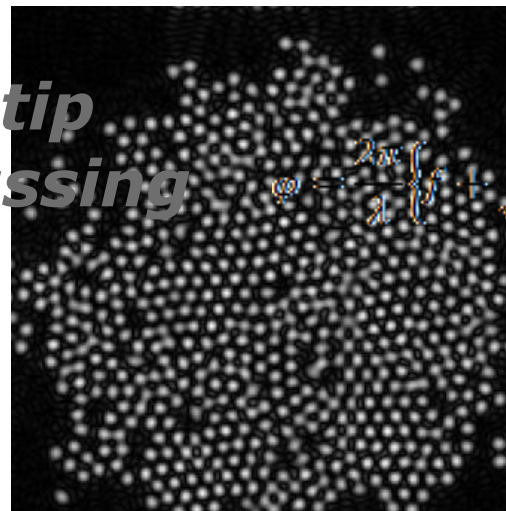
Fourier Plane



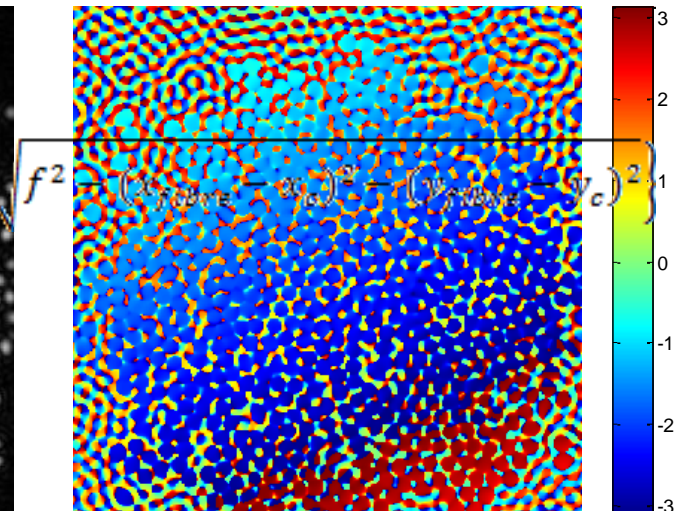
Filtered FT



Amplitude



Phase



Complex
Add curvature, tip
and tilt for focussing
and scanning:
profile at:
fibre
input:

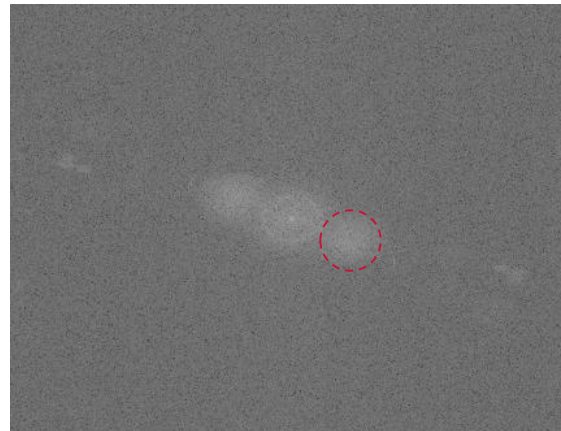
$$\omega = \frac{2\pi c}{\lambda} \left(f + \sqrt{f^2 - (x_{\text{wave}} - x_c)^2 - (y_{\text{wave}} - y_c)^2} \right)$$

Phase Calculation

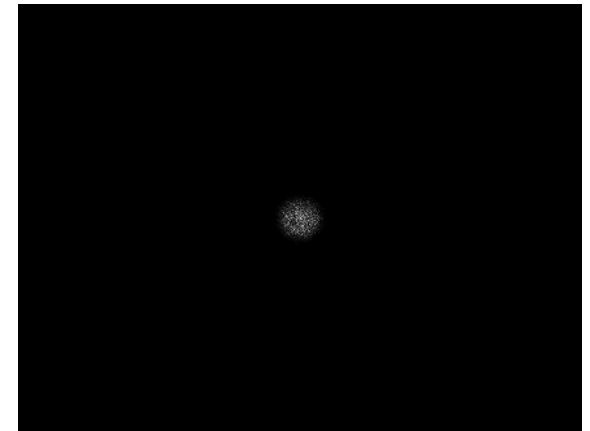
Interferogram



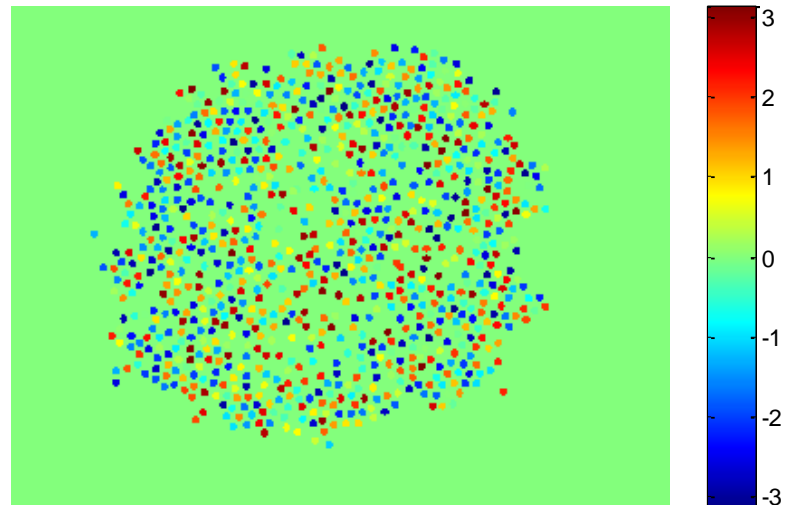
Fourier Transform



Filter and shift



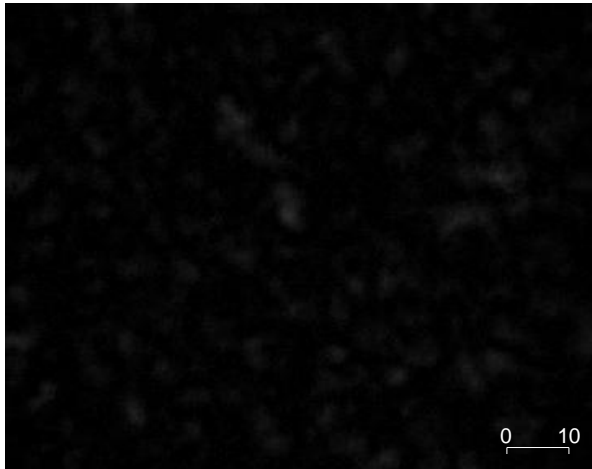
***Inverse FT
and take
phase:***



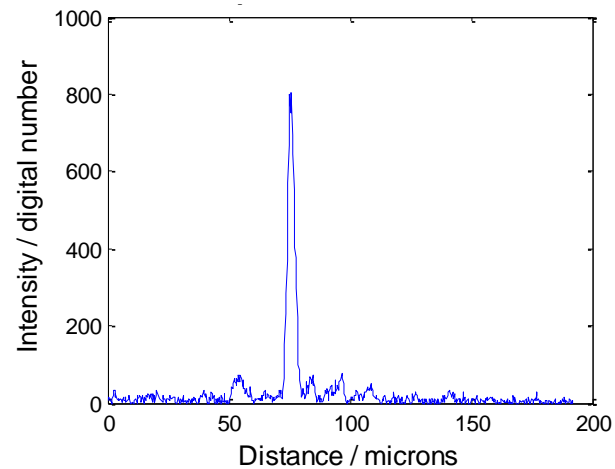
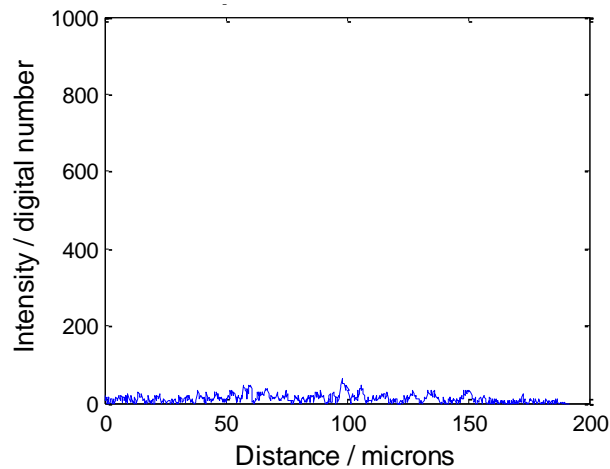
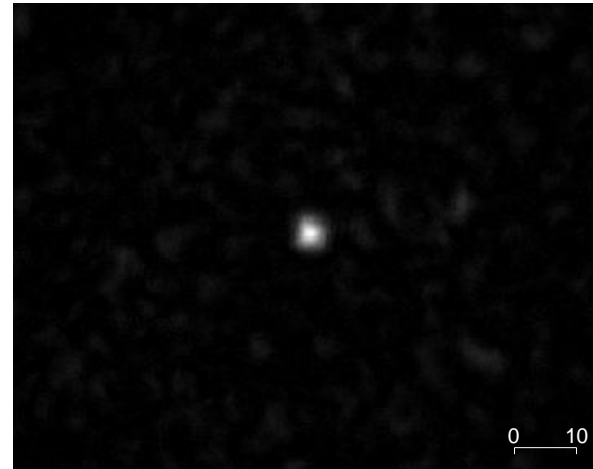
Results

Phase correction and focussing

Before Correction



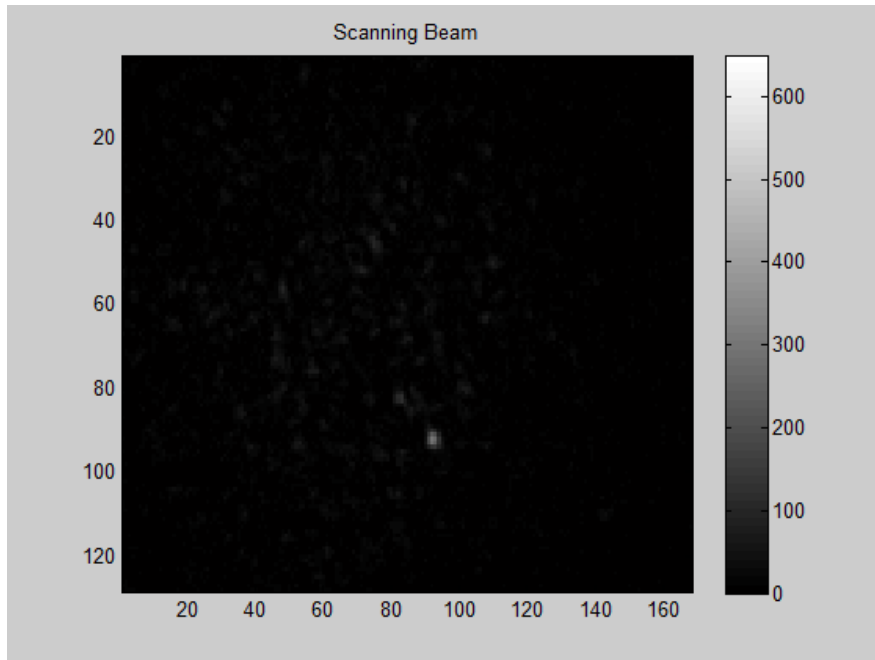
After Correction



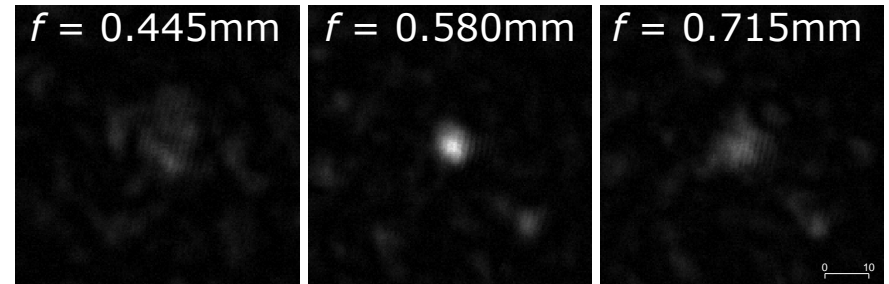
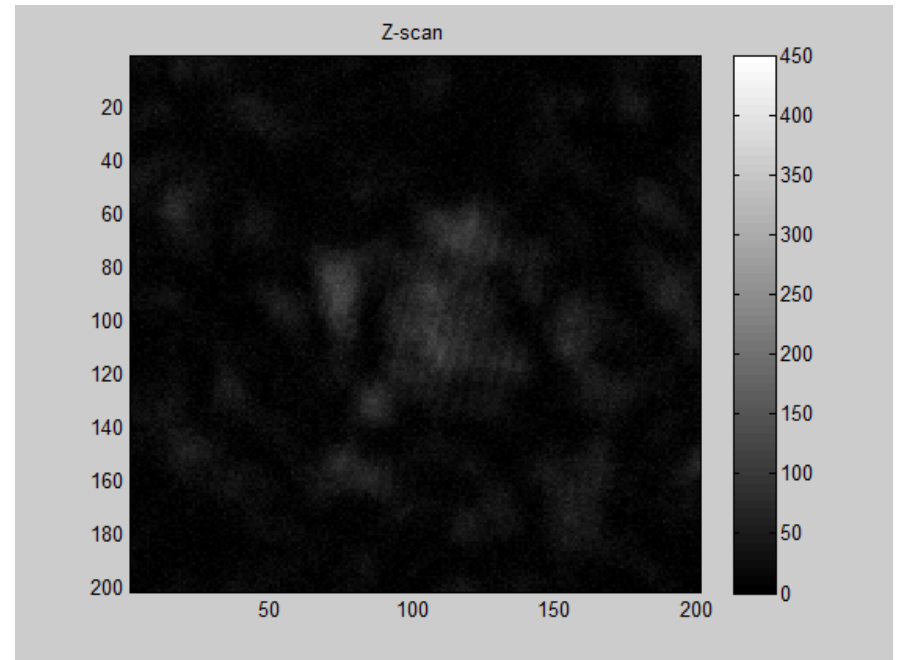
Results

Beam scanning

x-y scanning



z scanning

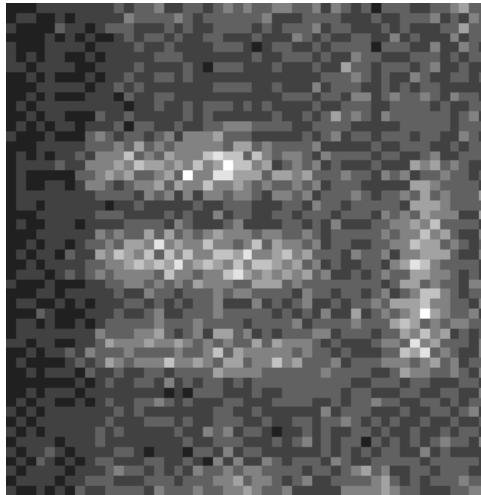


Results

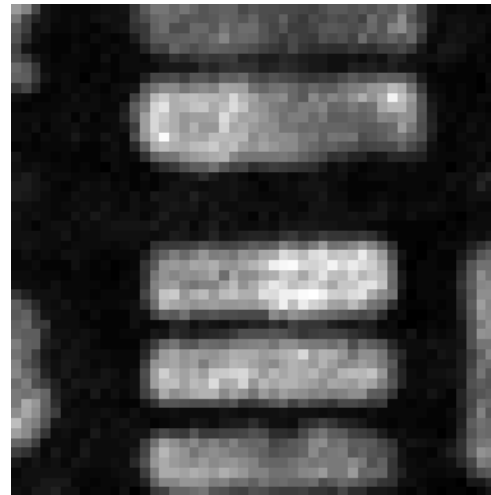
Imaging of USAF 1951 resolution test chart

*Sequentially
scanned
transmitted
light images:*

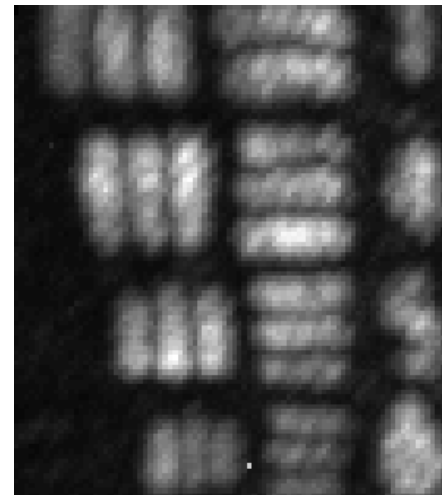
Mean Value



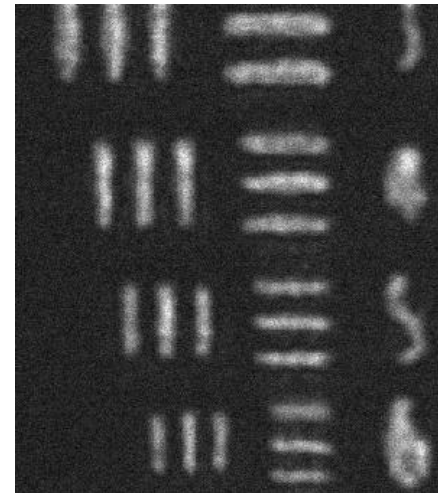
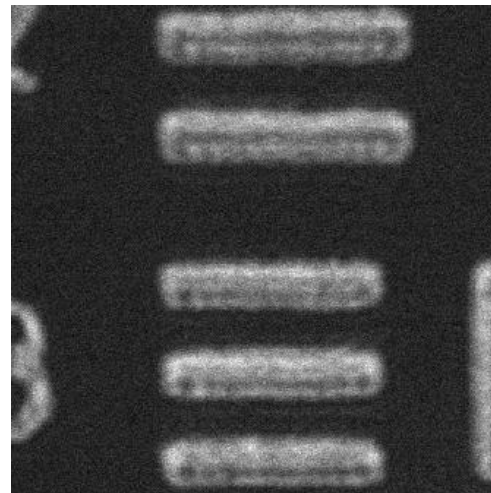
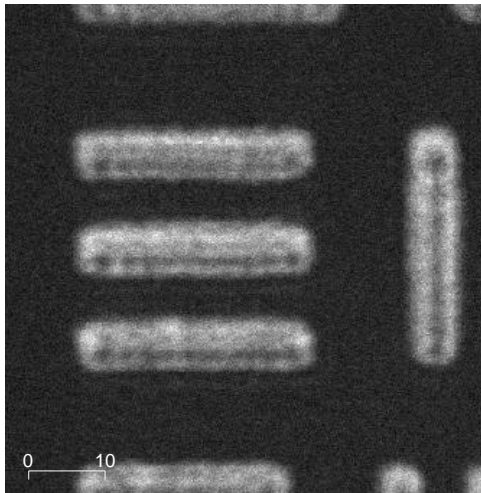
Max Value



Max Value



*Corresponding
wide-field
transmitted
light images:*



Conclusions

- Have demonstrated proof of principle of a novel method for beam focussing and scanning in a microconfocal endoscope.
- This allows focussing, 3D beam scanning and imaging.
- Requires no optical or mechanical distal components.

Thank You

Alex Thompson, Chris Dunsby, Carl Paterson, Yuhong Wan,
Mark Neil, Paul French

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