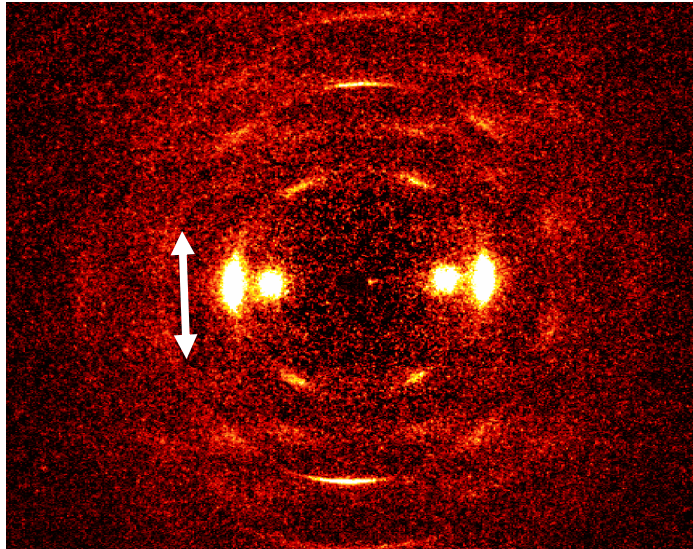
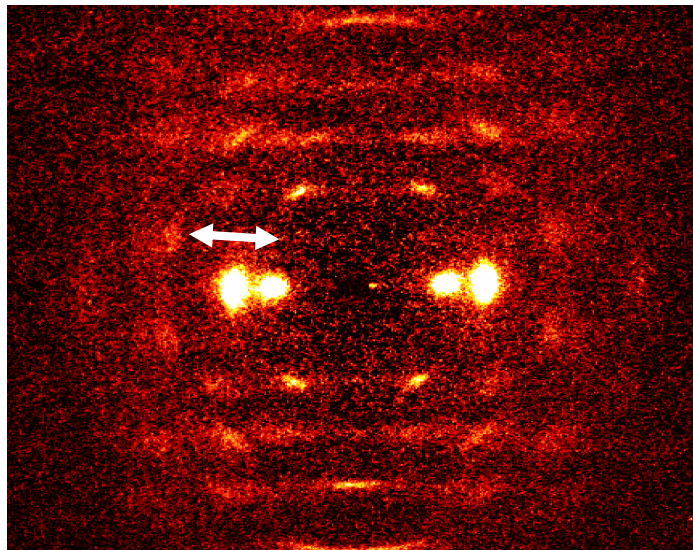


## 2.1.3 Morphologie von Zellulose

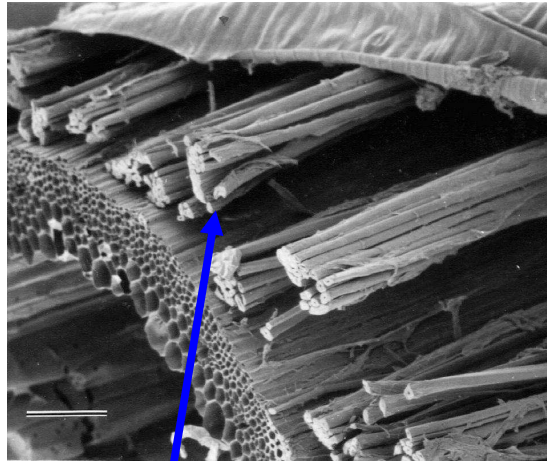


Untersuchung **einzelner** Fasern möglich; **lokale** Bestimmung von Parametern wie:

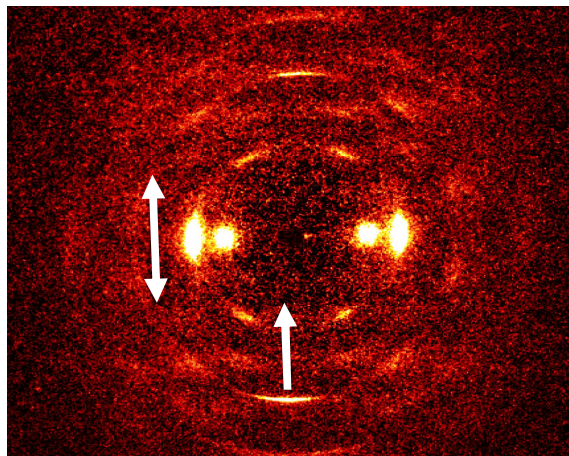
- *Orientierungsverteilung* der Mikrofibrillen
- *Kristallgröße*
- *Kristallinität* (Anteil kristallinen Materials)



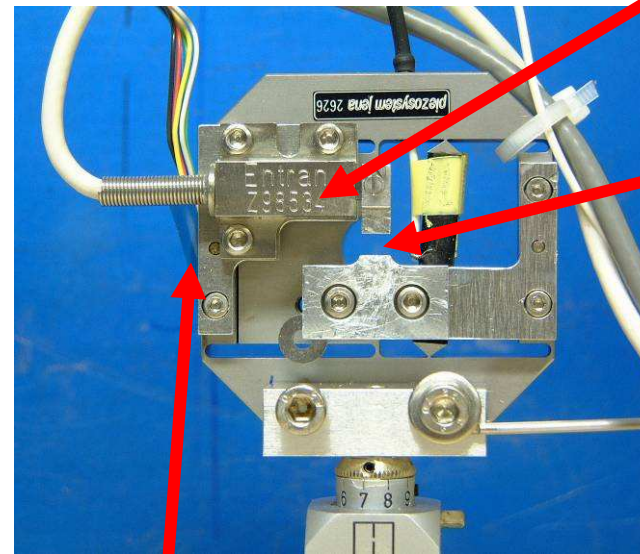
# Mikroskopische *in situ* Streckexperimente



Flachfasern:  
hochorientierte Zellulose



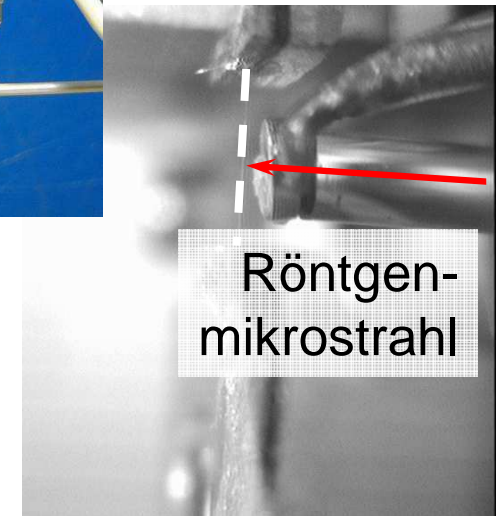
Piezo-Streckzelle für  
*in situ* Röntgenstreuung an  
Einzelfasern



Kraftsensor

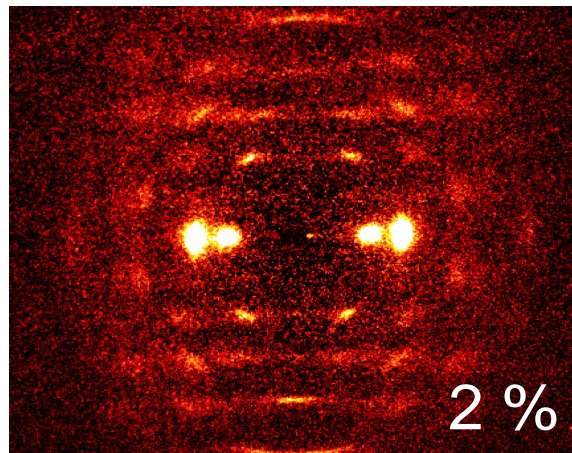
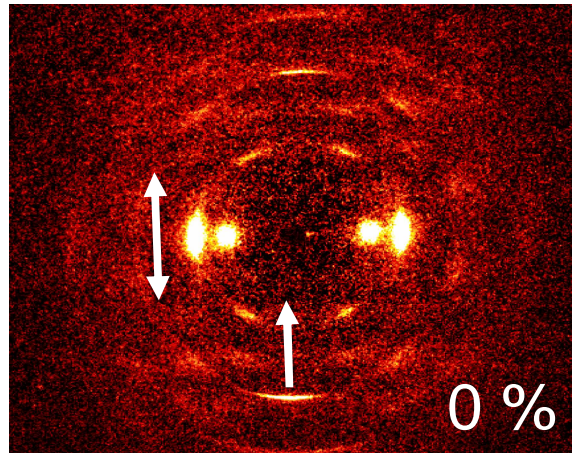
Faser

Dehnungs-  
meßstreifen

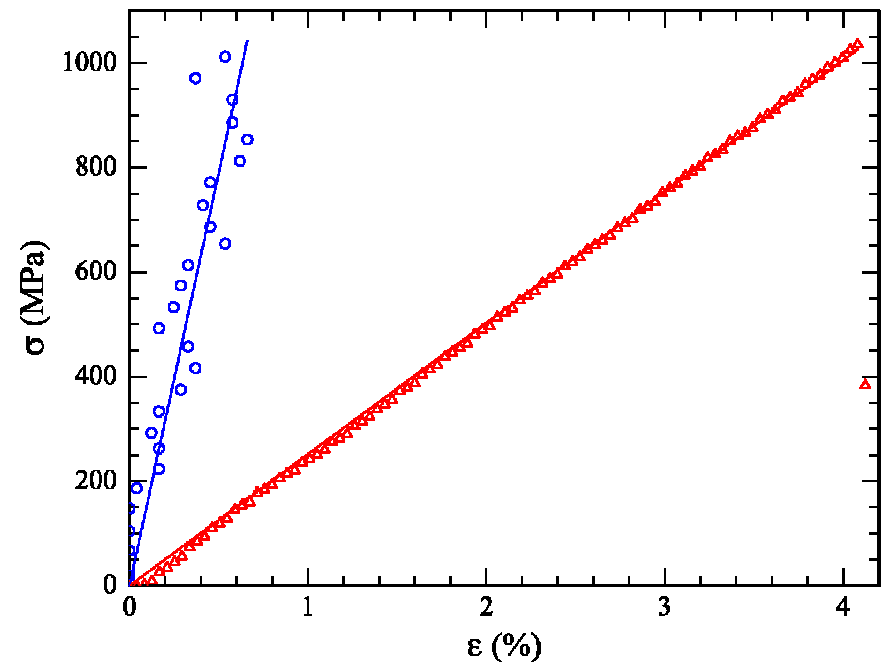
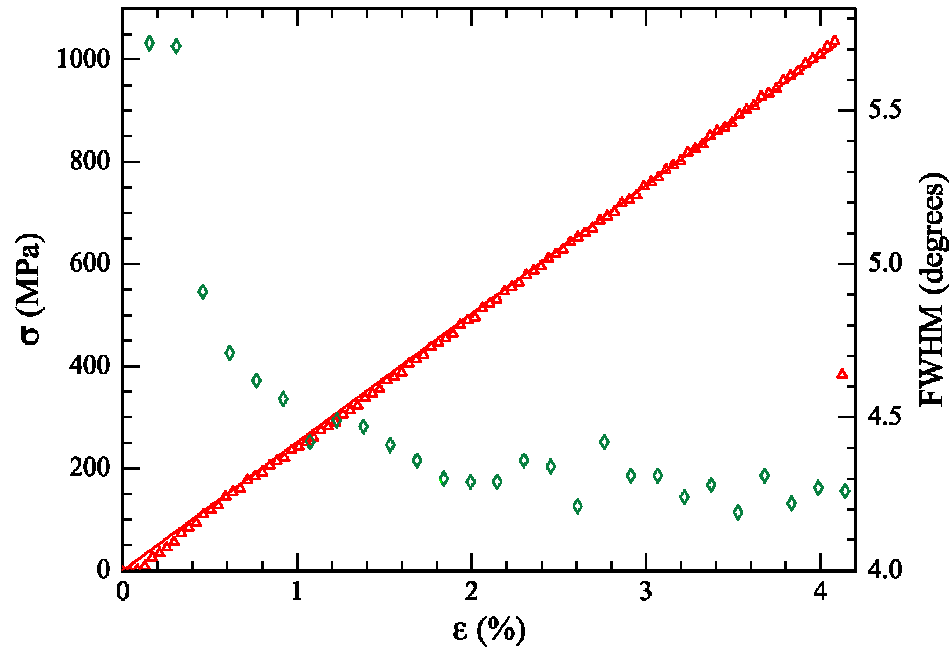


Röntgen-  
mikrostrahl

# Streckexperimente an einzelnen Flachfasern

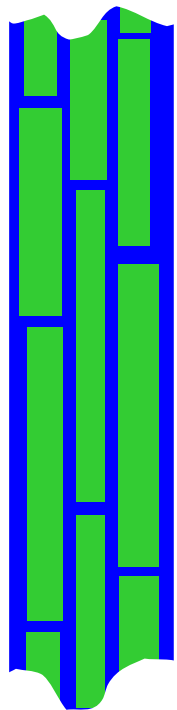


0.067 % / s  
2 s pro Bild



K. Kölln, I. Grotkopp, M. Burghammer, S. V. Roth,  
S. S. Funari, M. Dommach, M. Müller.  
*J. Synchr. Rad.* **12**, 739-744 (2005)

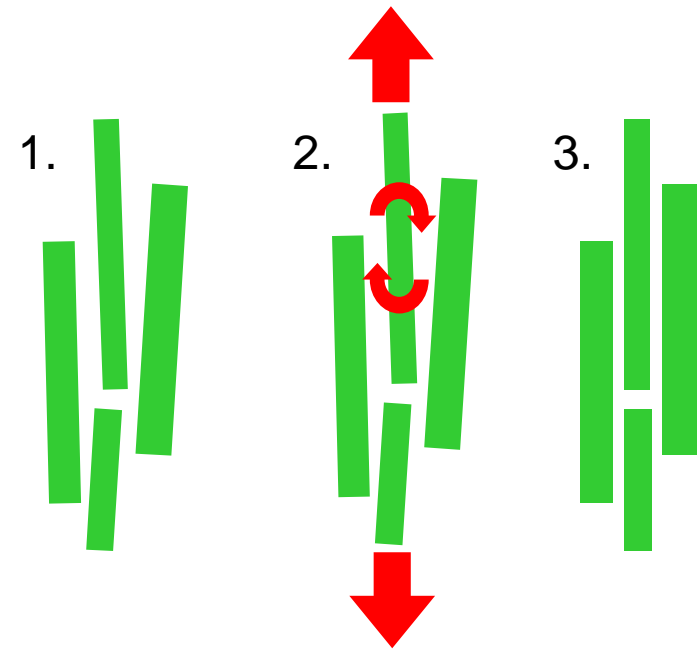
# Die Zellulosefaser als Nanokomposit



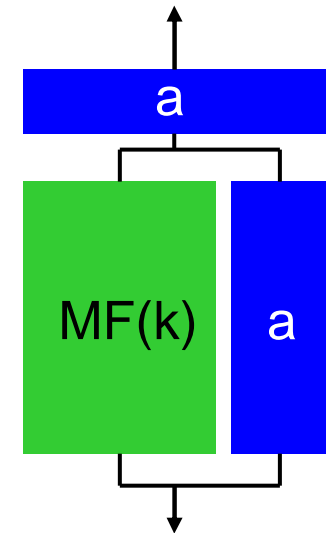
kristalline Mikrofibrillen  
eingebettet in  
amorphe Matrix

Hemicellulose (Polysaccharide)  
evtl. + Lignin = Verholzen

Rotation  
der Mikrofibrillen



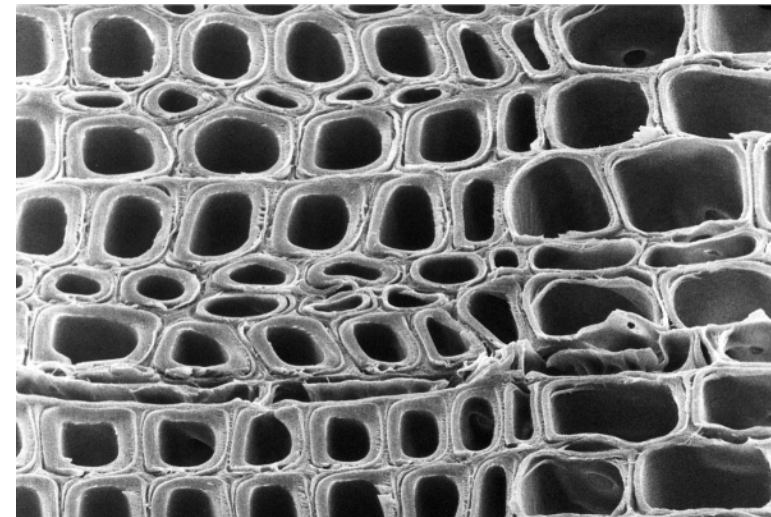
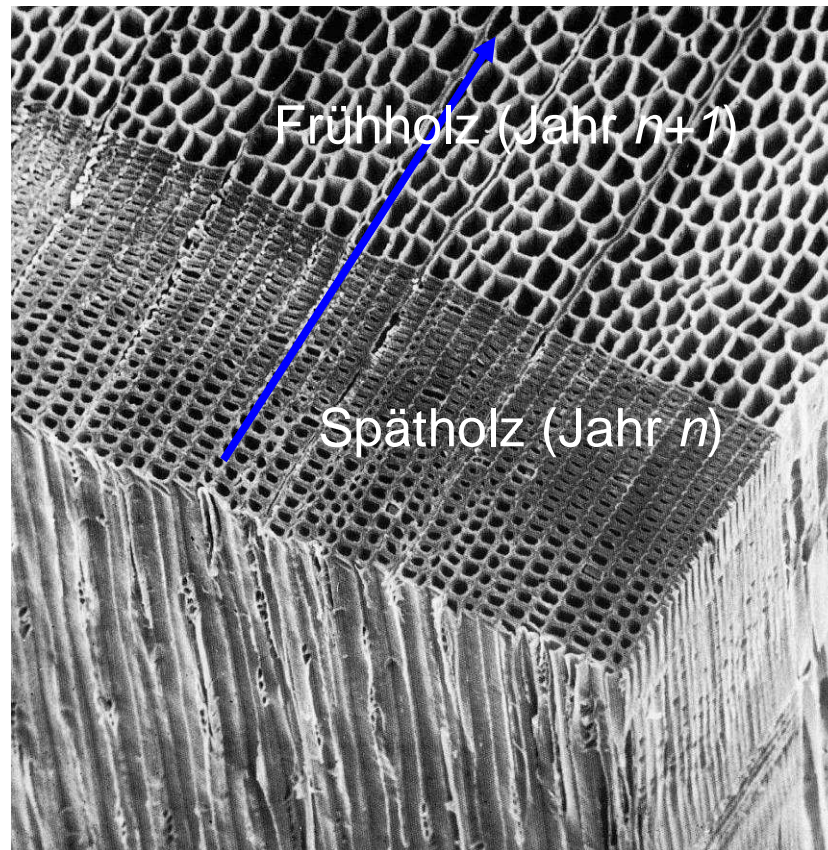
Dehnung  
der Mikrofibrillen



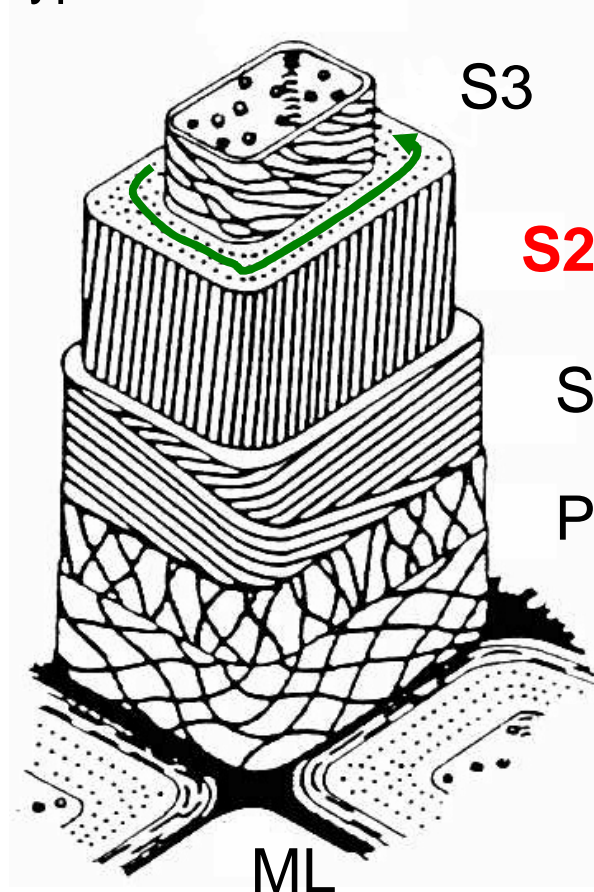
## 2.1.4 Mikro- und Nanostruktur von Holz

makroskopisch  $\Rightarrow$  mikroskopisch: **Jahrringe**

Dichtevariation: - **Frühholz:** große Zellen, dünne Wände  
- **Spätholz:** kleine Zellen, dicke Wände



## typische Nadelholzzelle



Zellwand ist in *Schichten* gegliedert:

ML: **Mittellamelle**, reich an Lignin

P: **primäre Zellwand**, schlecht kristalline Zellulose, keine Vorzugsorientierung

S1, S2, S3: **sekundäre Zellwand**, orientierte Zellulose, lignifiziert

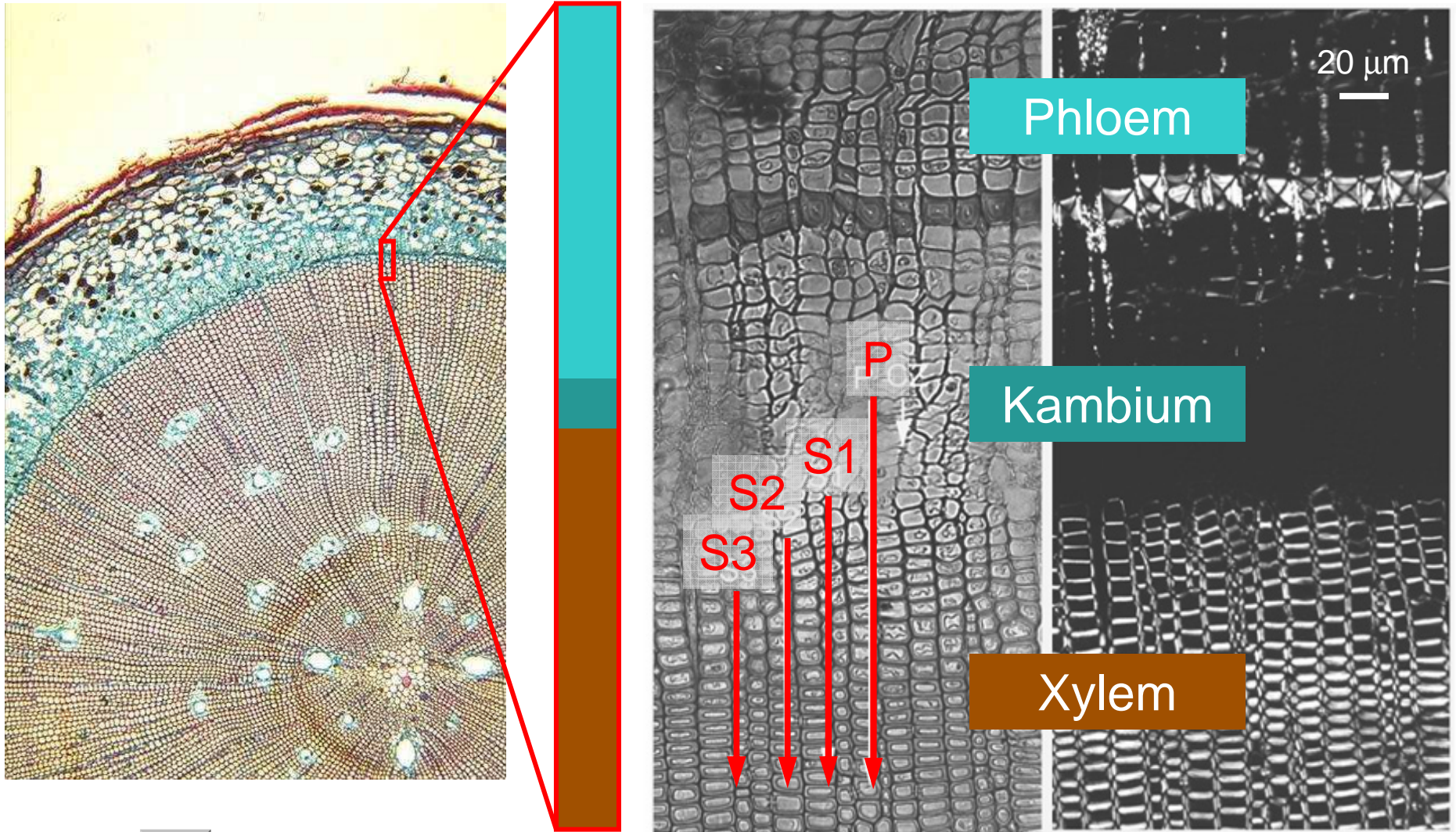
- **helikale** Struktur
- unterschiedlicher Steigungswinkel in S1-S3
- >80% der Dicke **S2**

Entstehung der Schichten beim **sekundären Dickenwachstum**

Wachstumszone: Cambium zwischen Rinde (Phloem) und Kern (Xylem, Tracheiden)

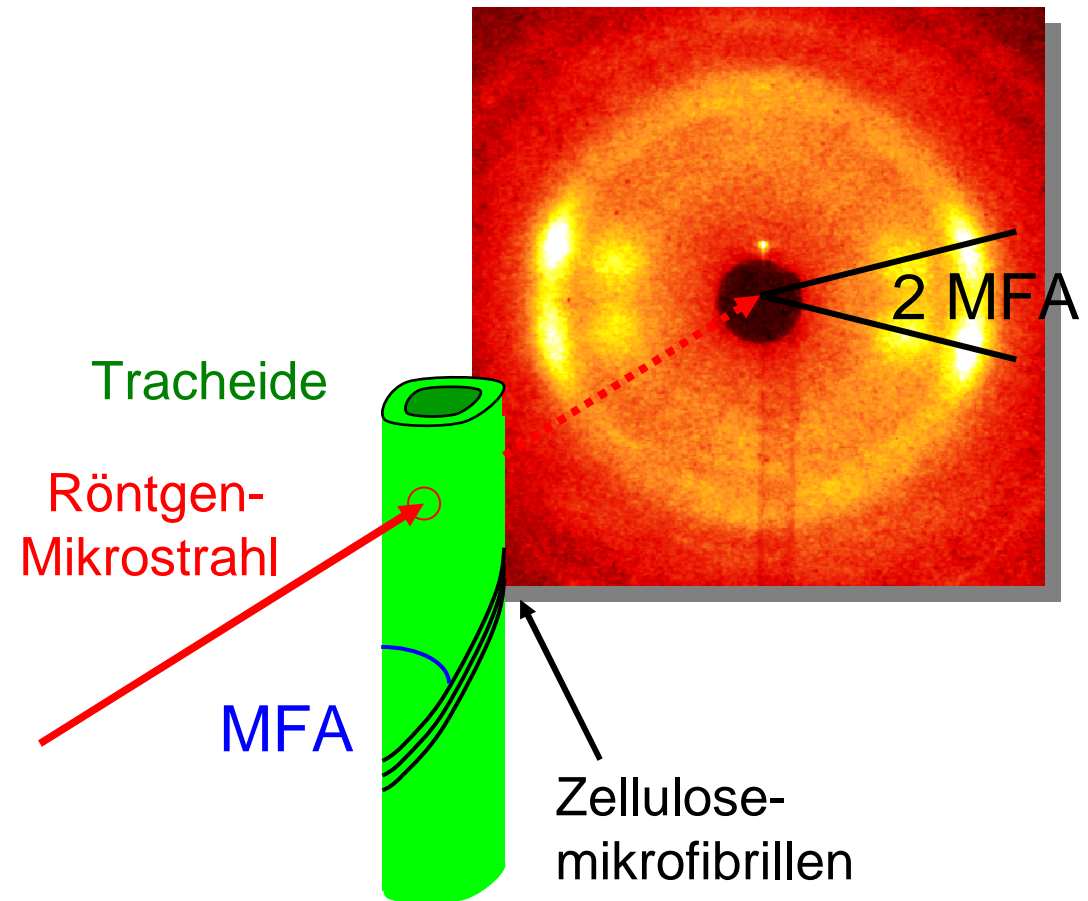
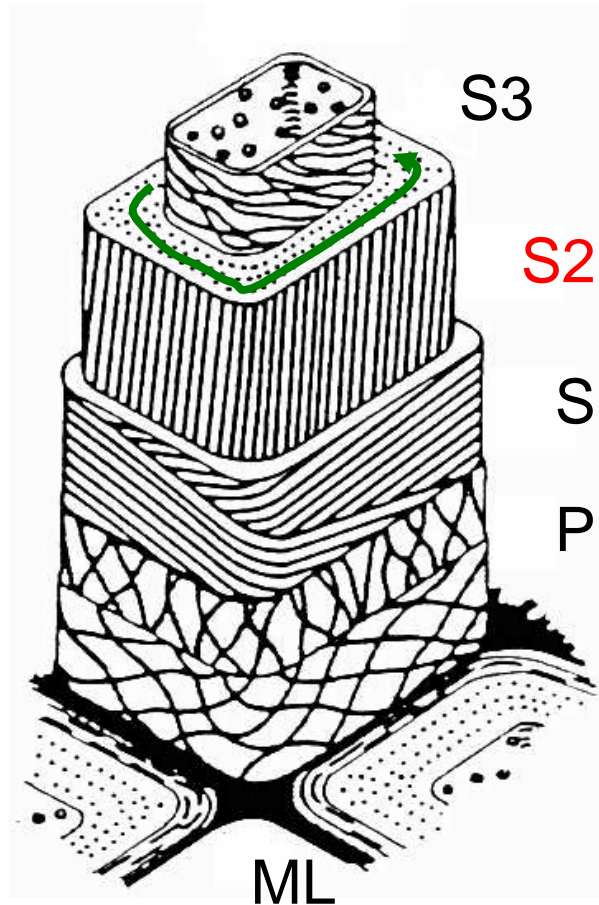
# Sekundäres Dickenwachstum: Differenzierung von Holzzellen <sup>71</sup>

Der Baum wächst außen (unter der Rinde)



optische Mikroskopie  
in normalem und polarisiertem Licht

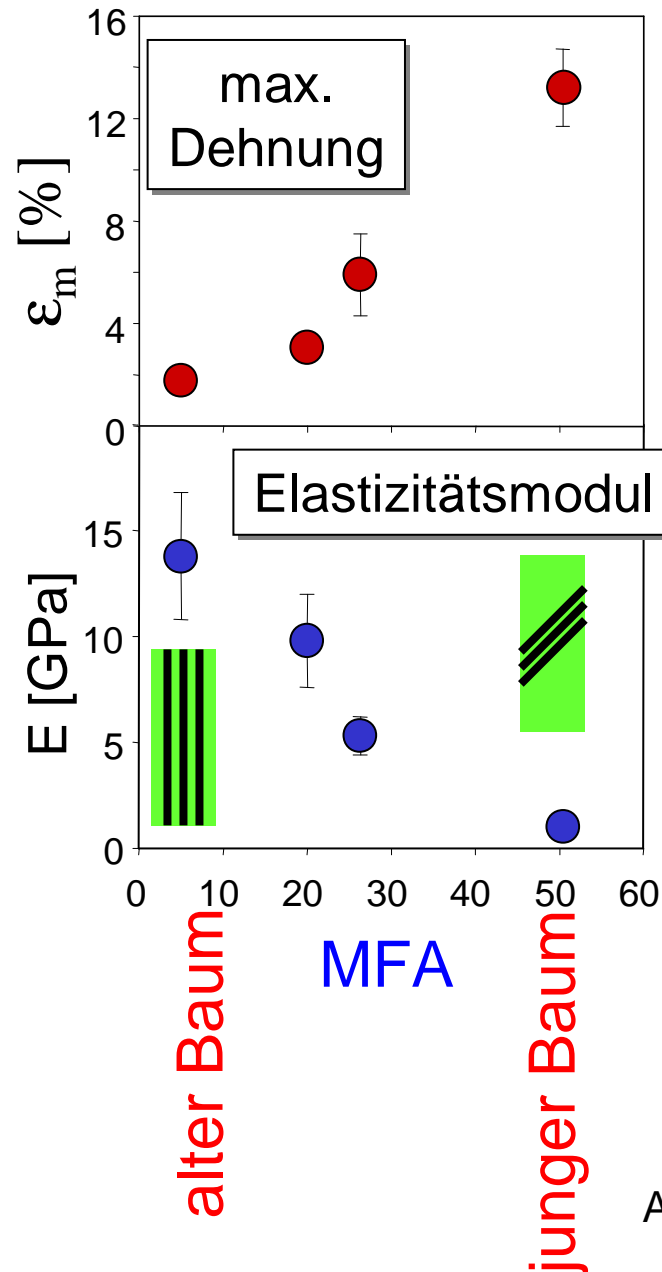
# Röntgenstreuung an Nadelholzzellen (Tracheiden)



**Mikrofibrillenwinkel (MFA)**  
=  $90^\circ$  – Steigungswinkel der Helix



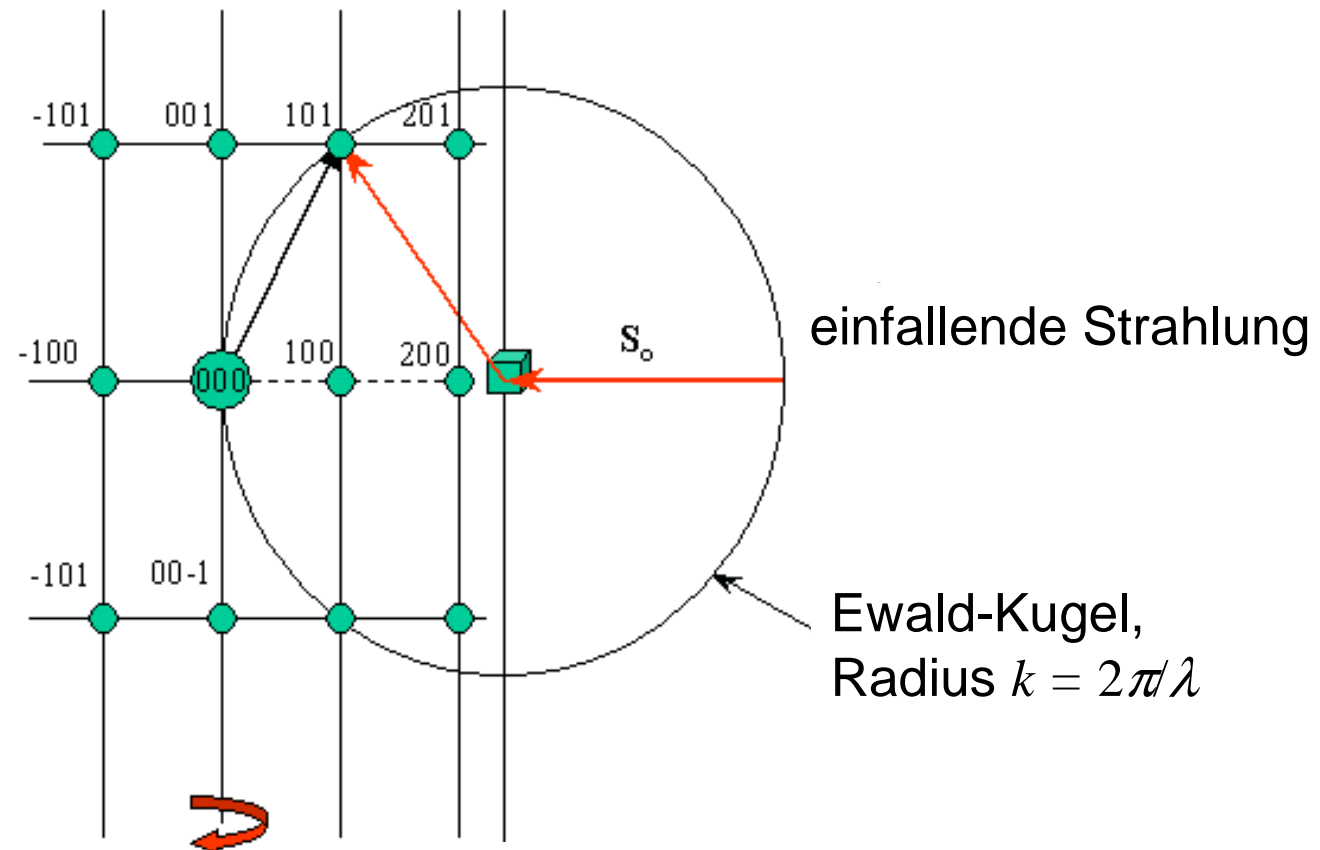
# Mechanische Optimierung von Bäumen



## Wiederholung: Ewald-Konstruktion

Formulierung der Beugungsbedingung:

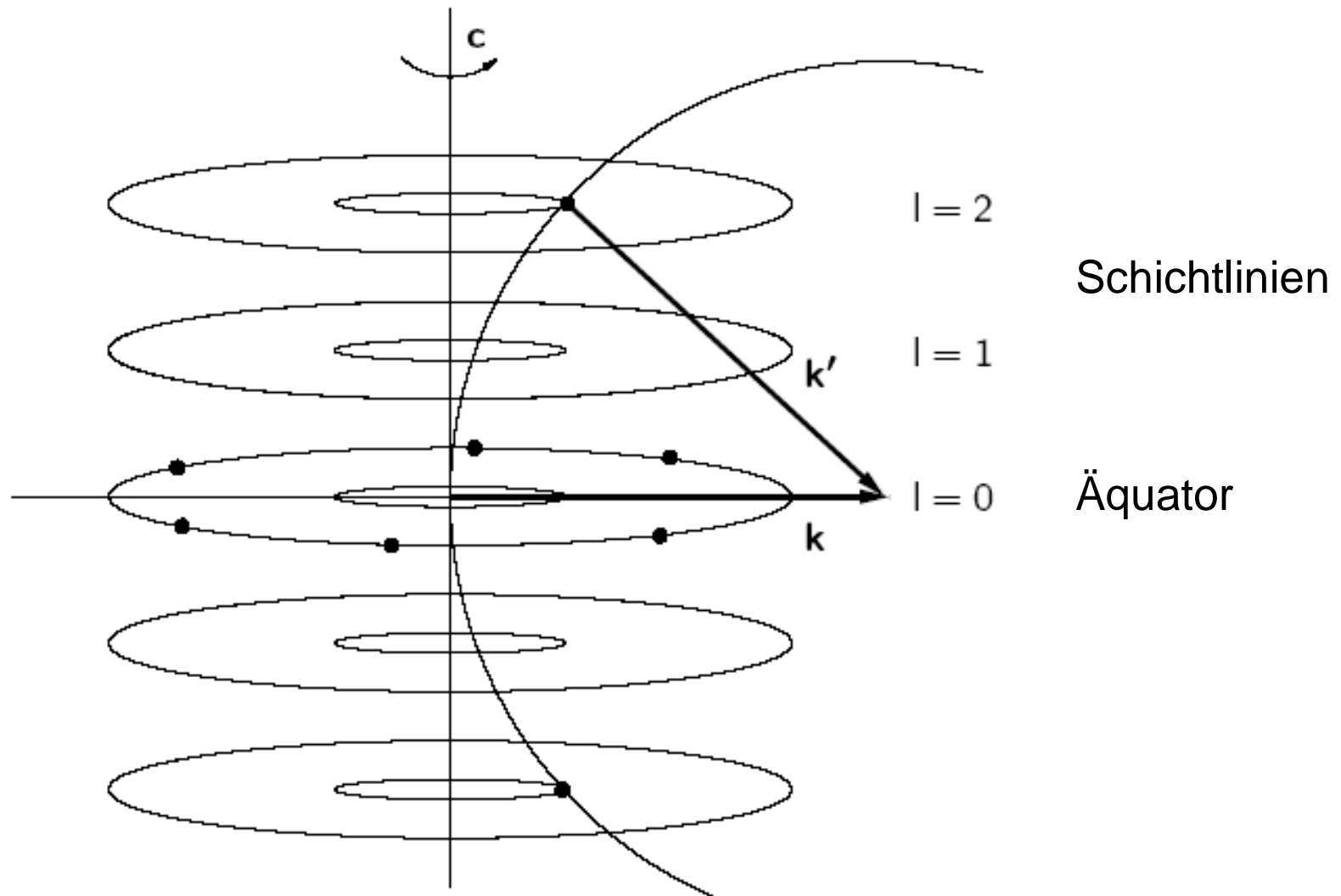
Wellenvektorübertrag  $\mathbf{Q}$  = reziproker Gittervektor  $\mathbf{G}$



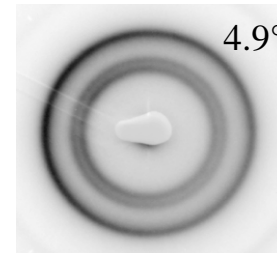
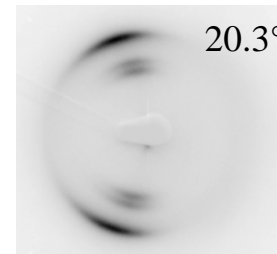
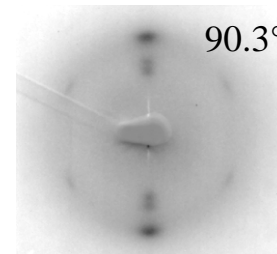
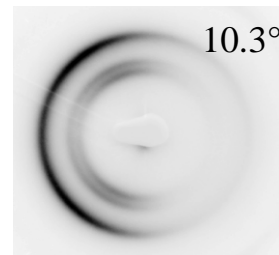
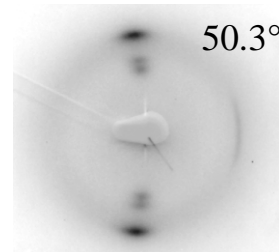
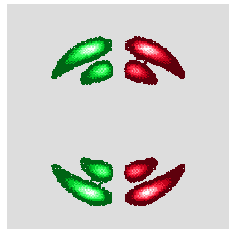
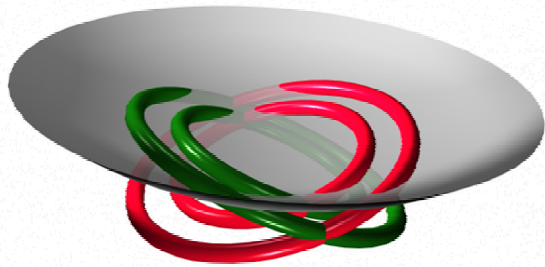
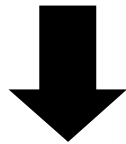
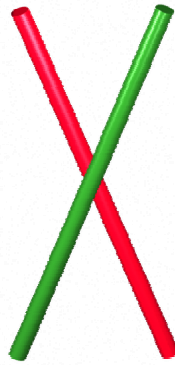
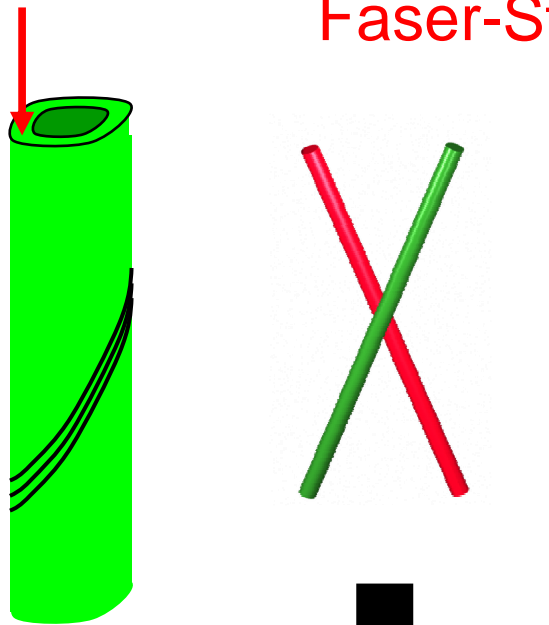
Drehkristallaufnahme  
= Fasertextur

# Ewald-Konstruktion für Fasertextur

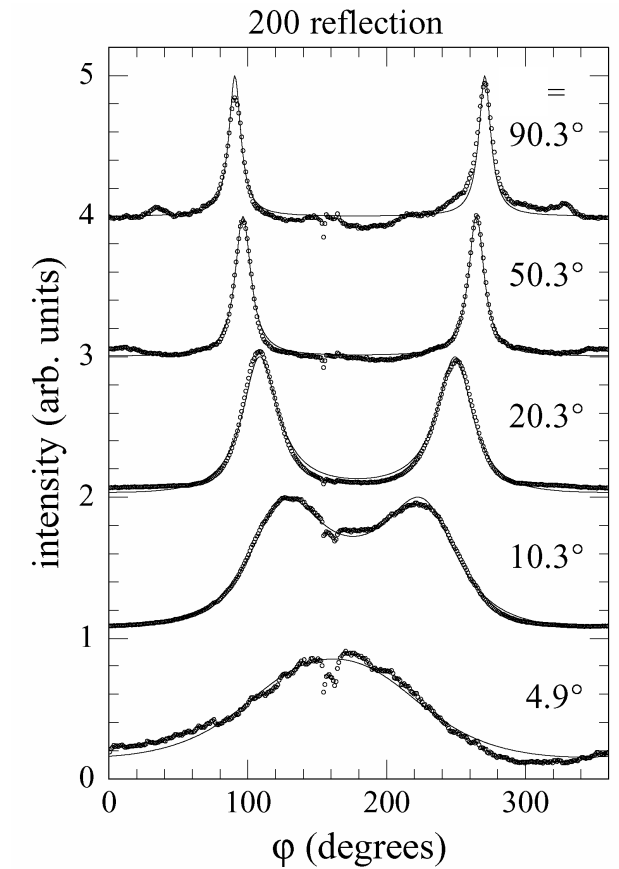
Drehachse = Faserachse (ausgezeichnet)



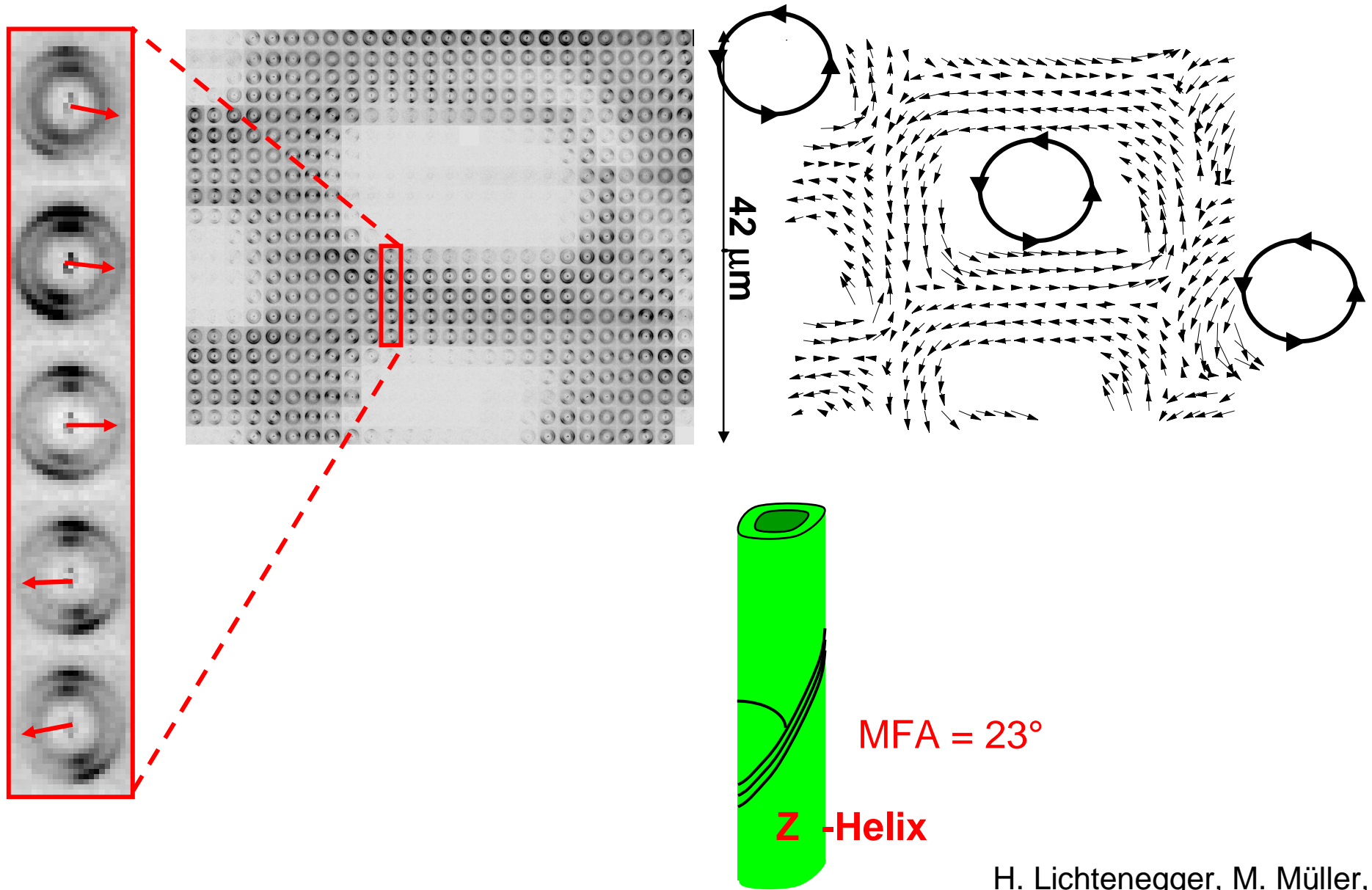
# Faser-Streugeometrie bei gekippten Fasern (gegen den Strahl)



## Azimuthale Scans



# Zellulose-Orientierung in Holz-Zellwänden



H. Lichtenegger, M. Müller,  
O. Paris, C. Riekkel, P. Fratzl  
*J. Appl. Cryst.* **32**, 1127-1133 (1999)

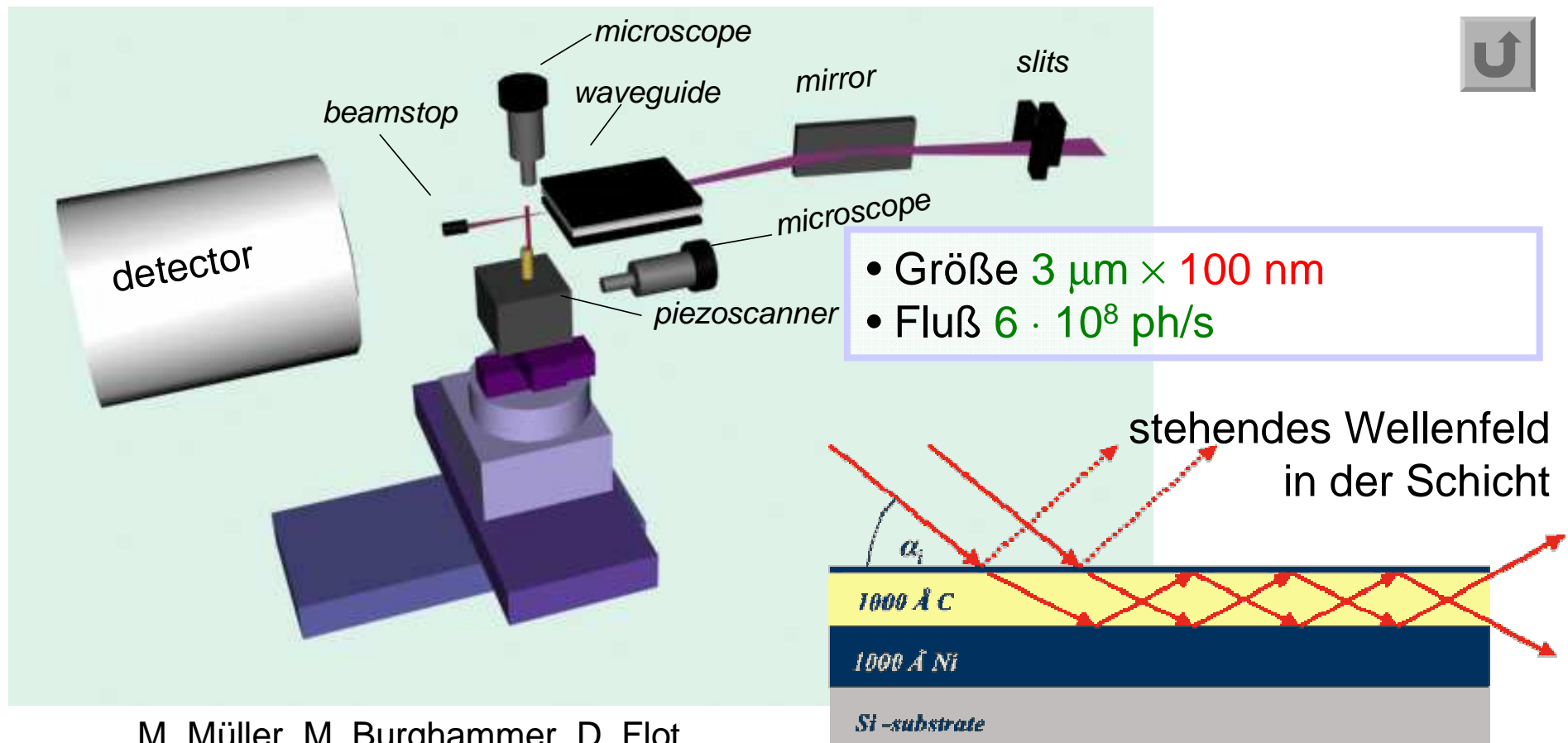
# MFA: The Movie



# Sub-Mikrometer-Ortsauflösung



ID13 Diffraction mit **Röntgen-Wellenleiter**

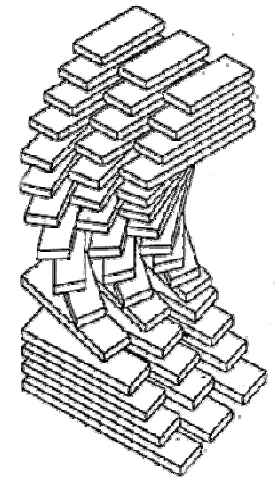
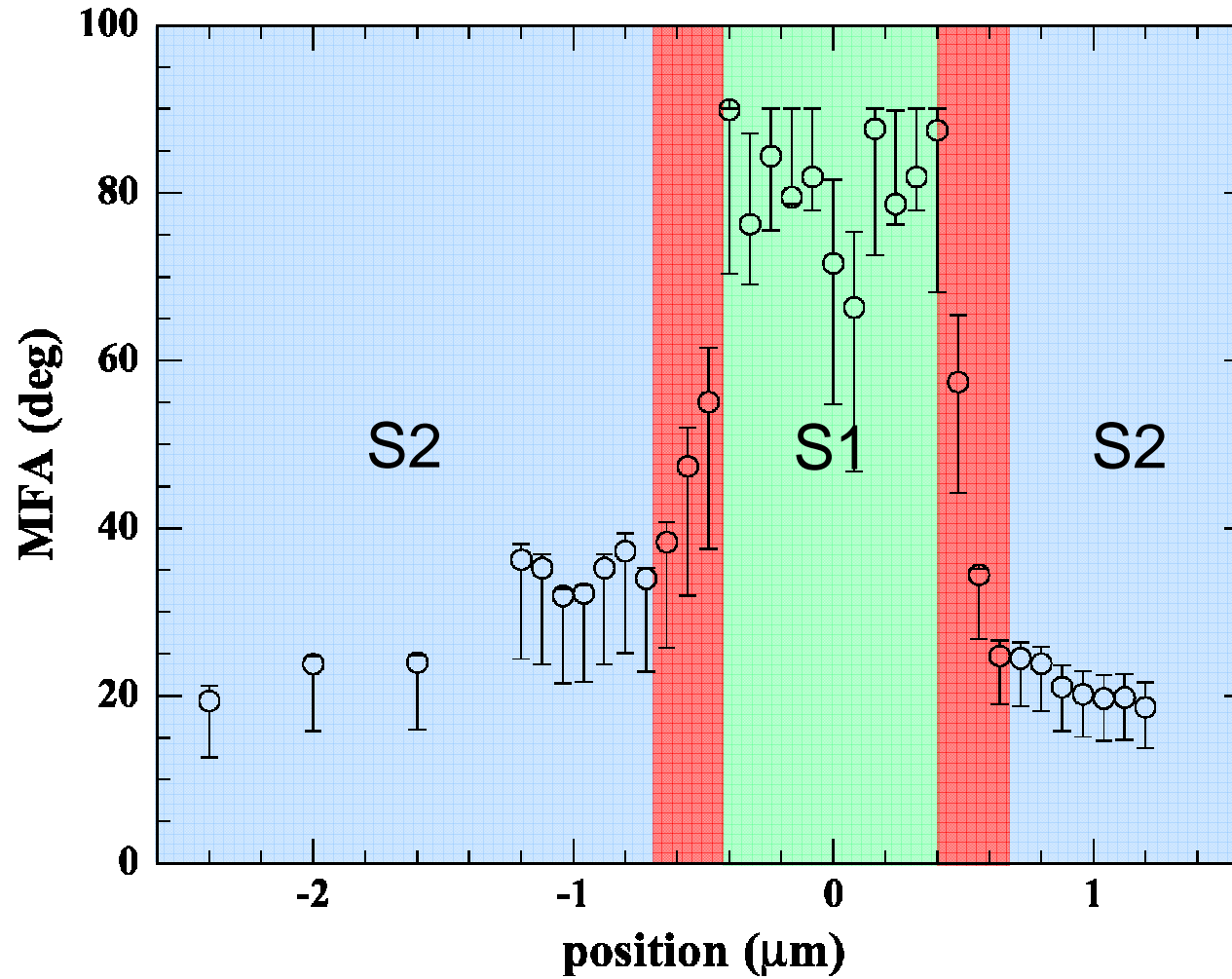


M. Müller, M. Burghammer, D. Flot,  
C. Riekell, C. Morawe, B. Murphy, A. Cedola  
*J. Appl. Cryst.* **33**, 1231-1240 (2000)

S. Di Fonzo, W. Jark, S. Lagomarsino,  
C. Giannini, L. De Caro, A. Cedola, M. Müller  
*Nature* **403**, 638-640 (2000)



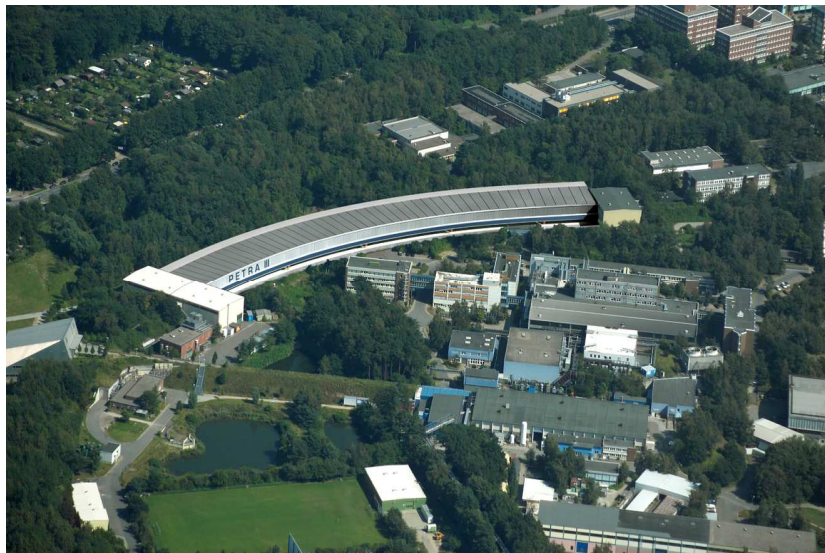
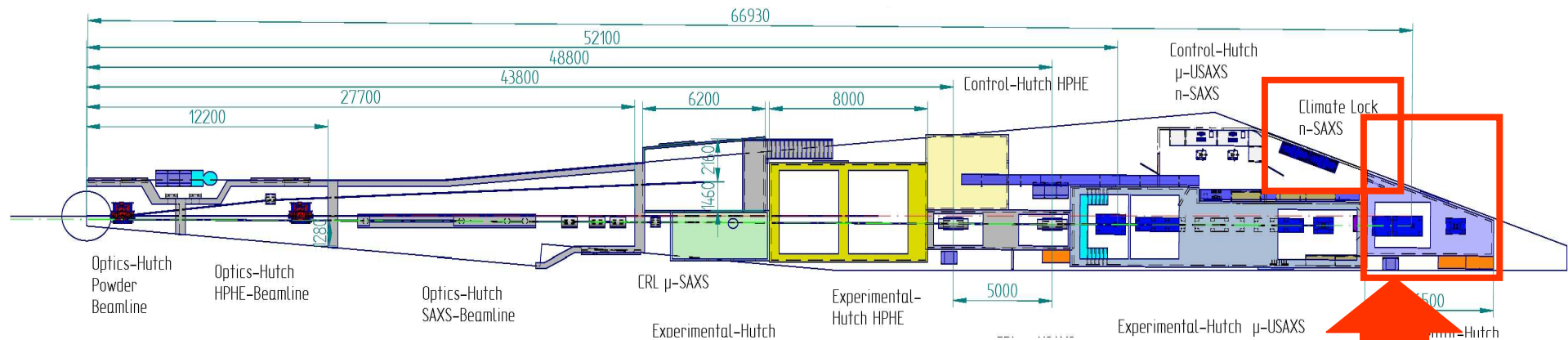
## Sub-Mikrometer-Ortsauflösung: Helikoidaler Übergang zwischen S1 und S2?





# Projekt an PETRA III: Nanofokus-Meßplatz

81



## Kiel:

- Christina Krywka (ab März 2008)
- Igor Krasnov
- M. M.

## Hamburg:

- Stephan V. Roth
- Ralph Döhrmann
- N. N. (Postdoc)
- N. N. (Techniker)

