

Entwicklungen auf dem Gebiet der Optik und Einfluss auf die Lichttechnik

Wolfgang Karthe

Fraunhofer Institut Angewandte Optik und
Feinmechanik

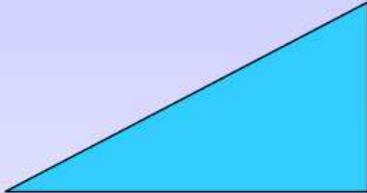
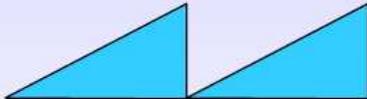
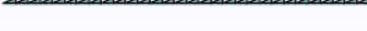


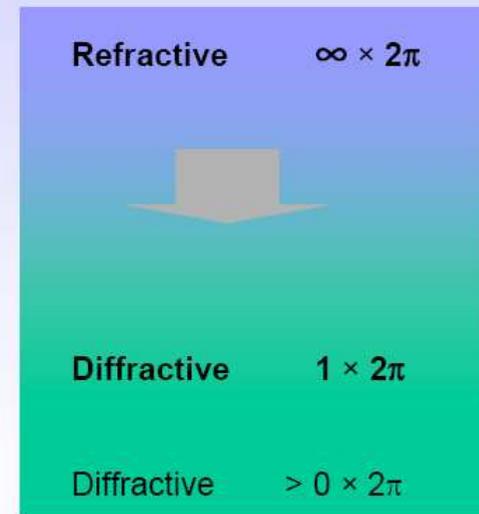
Gliederung:

- Einführung
- Grundlagen der Mikrooptik
- Informationsgewinnung (Kameras, strukturierte Beleuchtung)
- Informationswiedergabe / Visualisierung
- Hinterleuchtung
- Laserquellen / Strahlformer
- Informationsspeicherung
- Effektive Medien / Mottenaugeneffekt
- Technologie

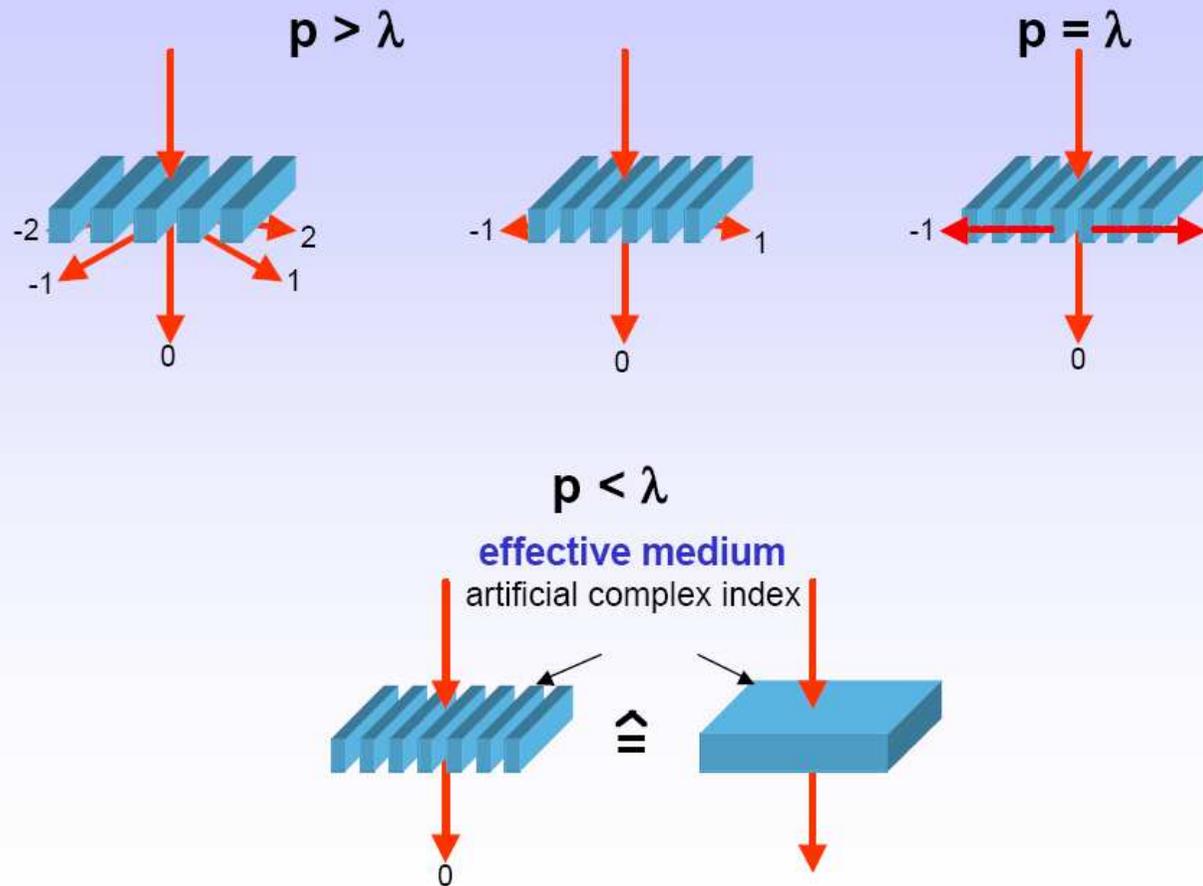


The transition from refractive to diffractive

profile	phase	diff. order
	$30 \times \lambda/\Delta n$	$30 \times 2\pi$
	$15 \times \lambda/\Delta n$	$15 \times 2\pi$
↓		
	$3 \times \lambda/\Delta n$	$3 \times 2\pi$
	$2 \times \lambda/\Delta n$	$2 \times 2\pi$
	$1 \times \lambda/\Delta n$	$1 \times 2\pi$



The decrease of the grating period



E. – Bernhard Kley, FSU-Jena/IAP

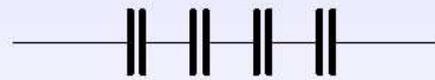
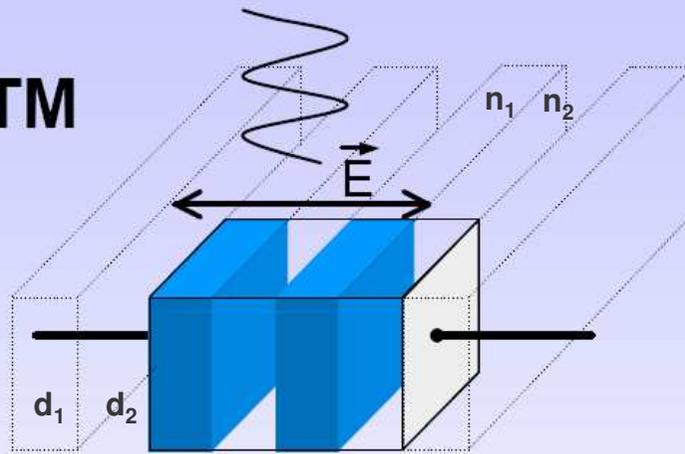
Archivierungsangaben

Seite 4



Effective Medium Theory

TM



$$1/C_1 + 1/C_2 + 1/C_3 + 1/C_4 = 1/C_{TM}$$

$$\frac{1}{n_{\perp}^2} = f_1 \frac{1}{n_1^2} + f_2 \frac{1}{n_2^2}$$

$$f_i = d_i / (d_1 + d_2)$$

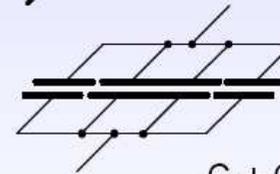
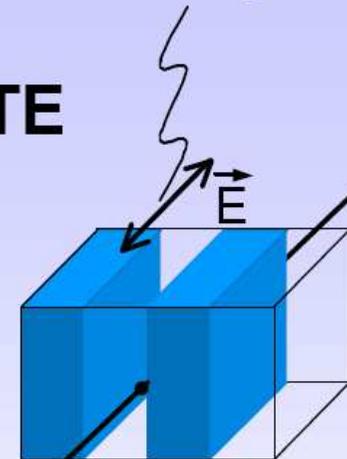
$$n = \sqrt{\epsilon}$$

$$C_{TM} \neq C_{TE}$$

$$\bar{\epsilon}_{TM} \neq \bar{\epsilon}_{TE}$$

$$n_{TM} \neq n_{TE}$$

TE



$$C_1 + C_2 + C_3 + C_4 = C_{TE}$$

$$n_{\parallel}^2 = f_1 n_1^2 + f_2 n_2^2$$

Effects:

- Birefringence
- Polarization

E. – Bernhard Kley, FSU-Jena/IAP



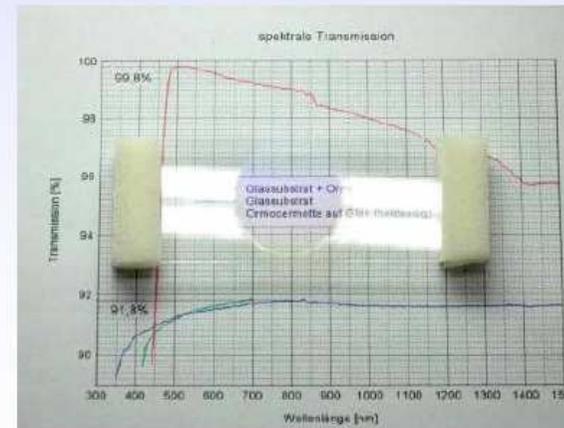
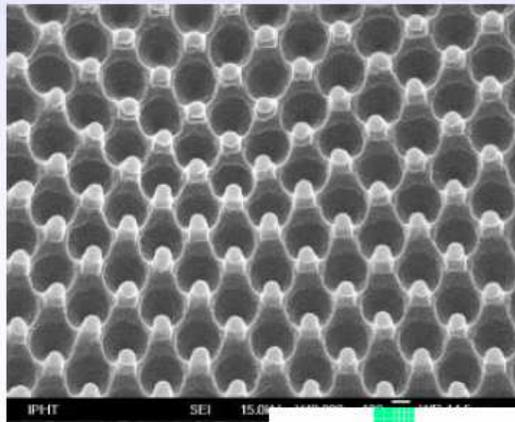
Effective Medium

vertical refractive index control → soft index transition → antireflection



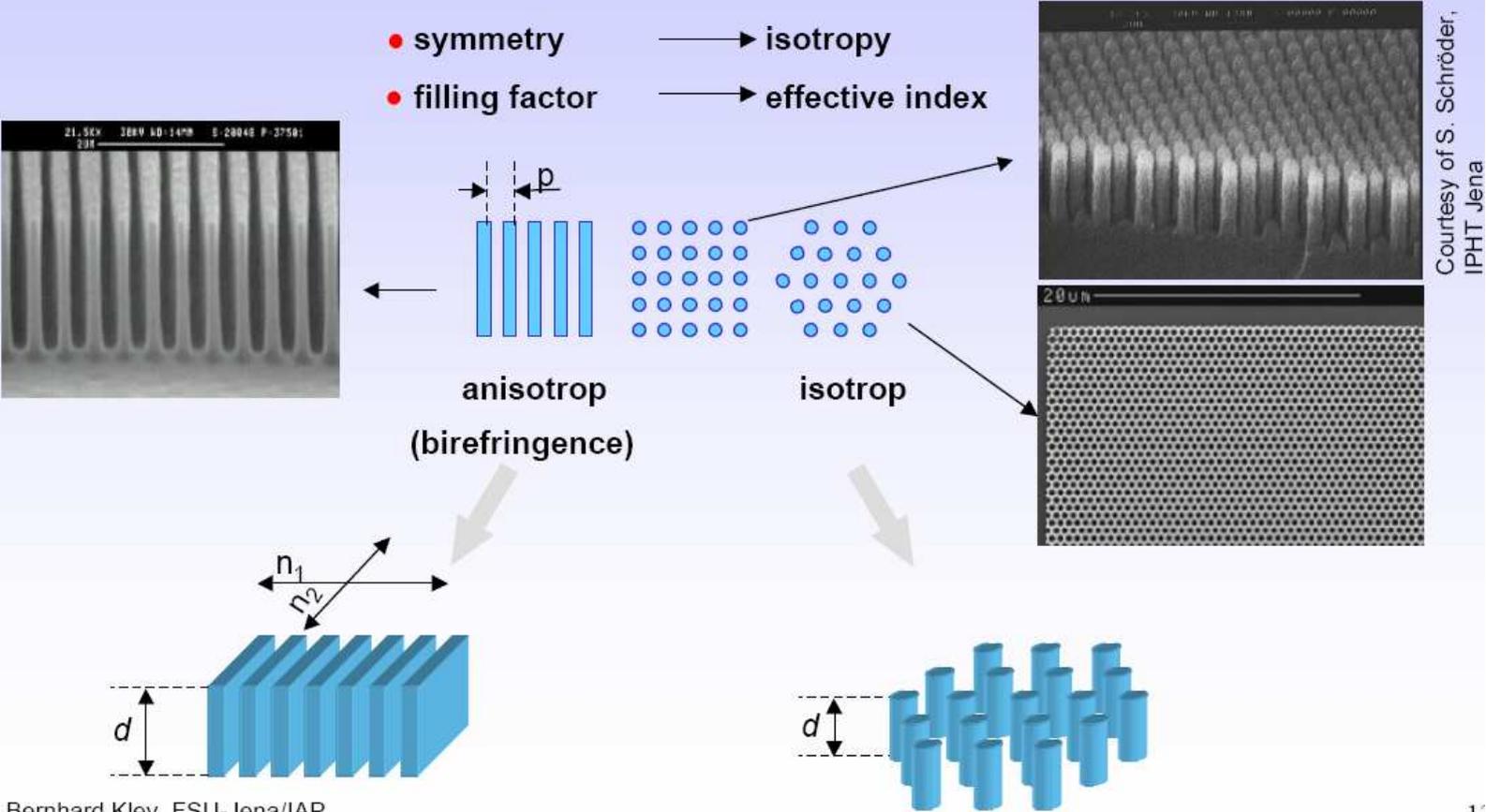
Application: antireflective surfaces (hot embossing, Fresnel Optics GmbH Apolda)

Conic grating profile for a soft index transition



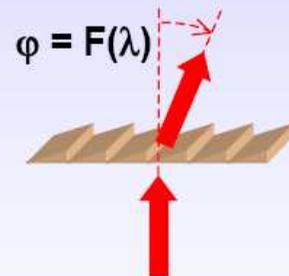
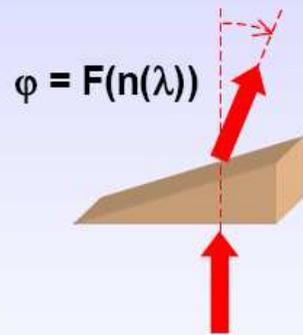
Effective Medium

Uniform control of the refractive index

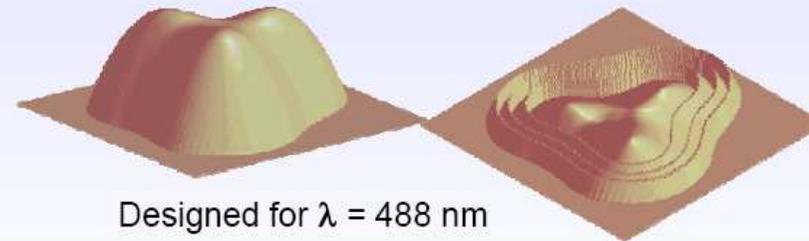
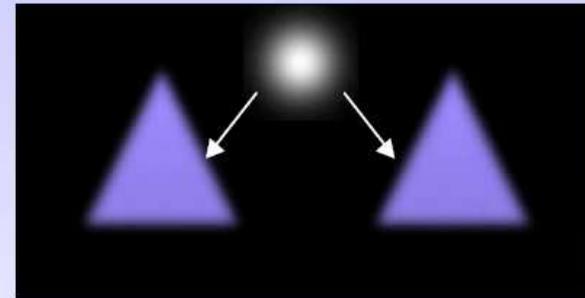


Problem: Diffractive or refractive?

Wavelength splitting



Beam shaping



high efficiency - efficiency control - wavelength separation/multiplexing - shallow surface profile - ...

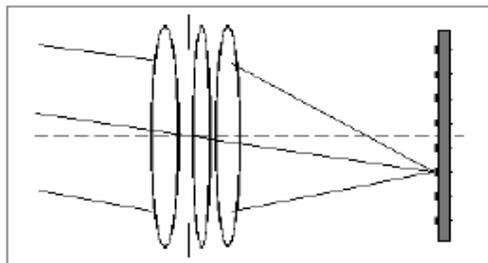
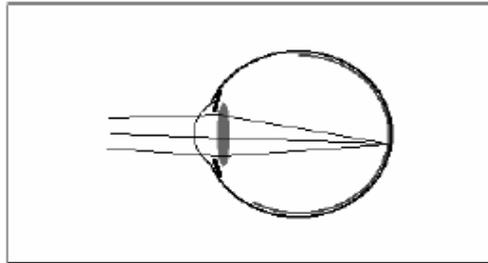
The application makes the choice

Fabrication technologies are challenged



Natürliche Bildsensoren und ihre technischen Äquivalente

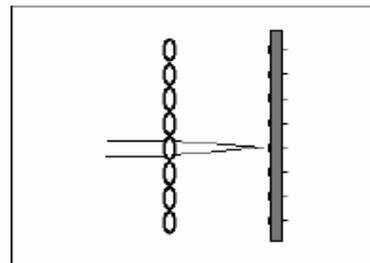
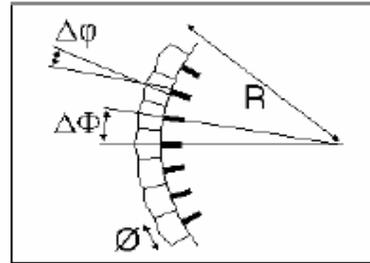
Single Aperture Eyes



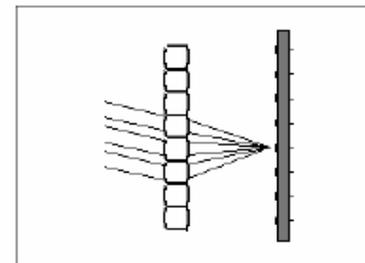
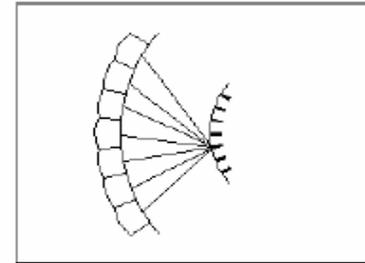
Klassische
abbildende
Systeme

Compound Eyes

Apposition



Superposition

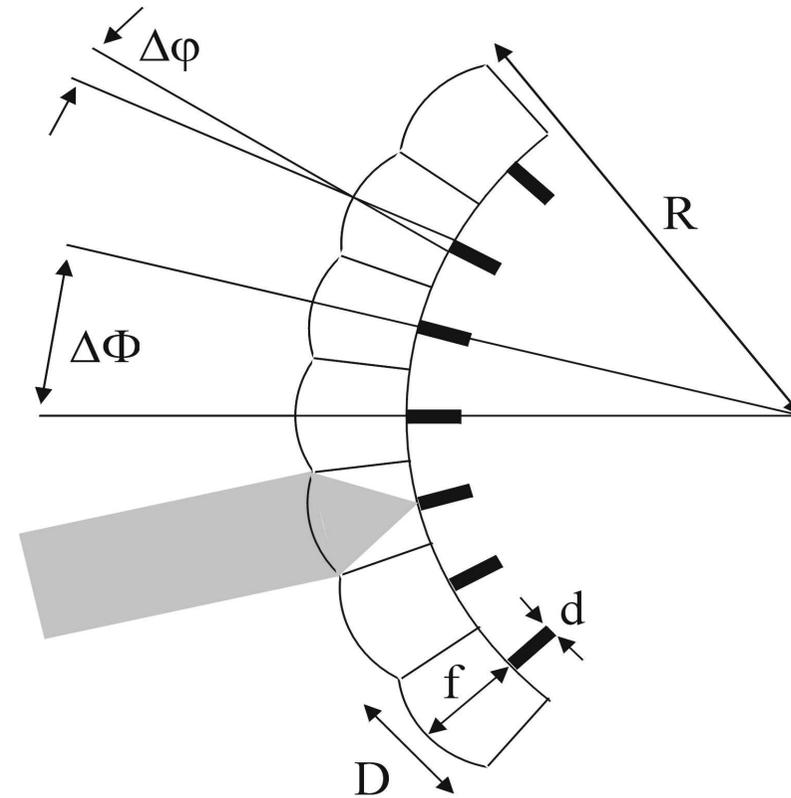
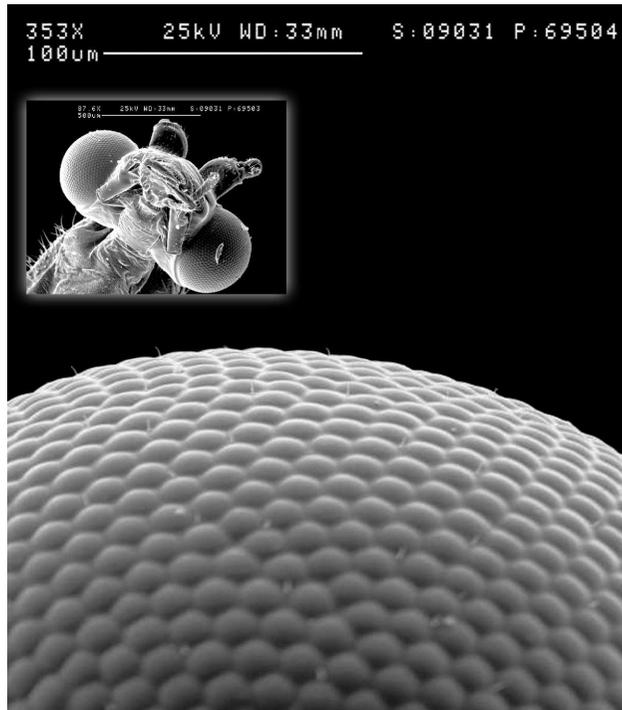


Eignung für mikrooptische Herstellungstechnologien der
Objektive (→ Mikrolinsenarrays)

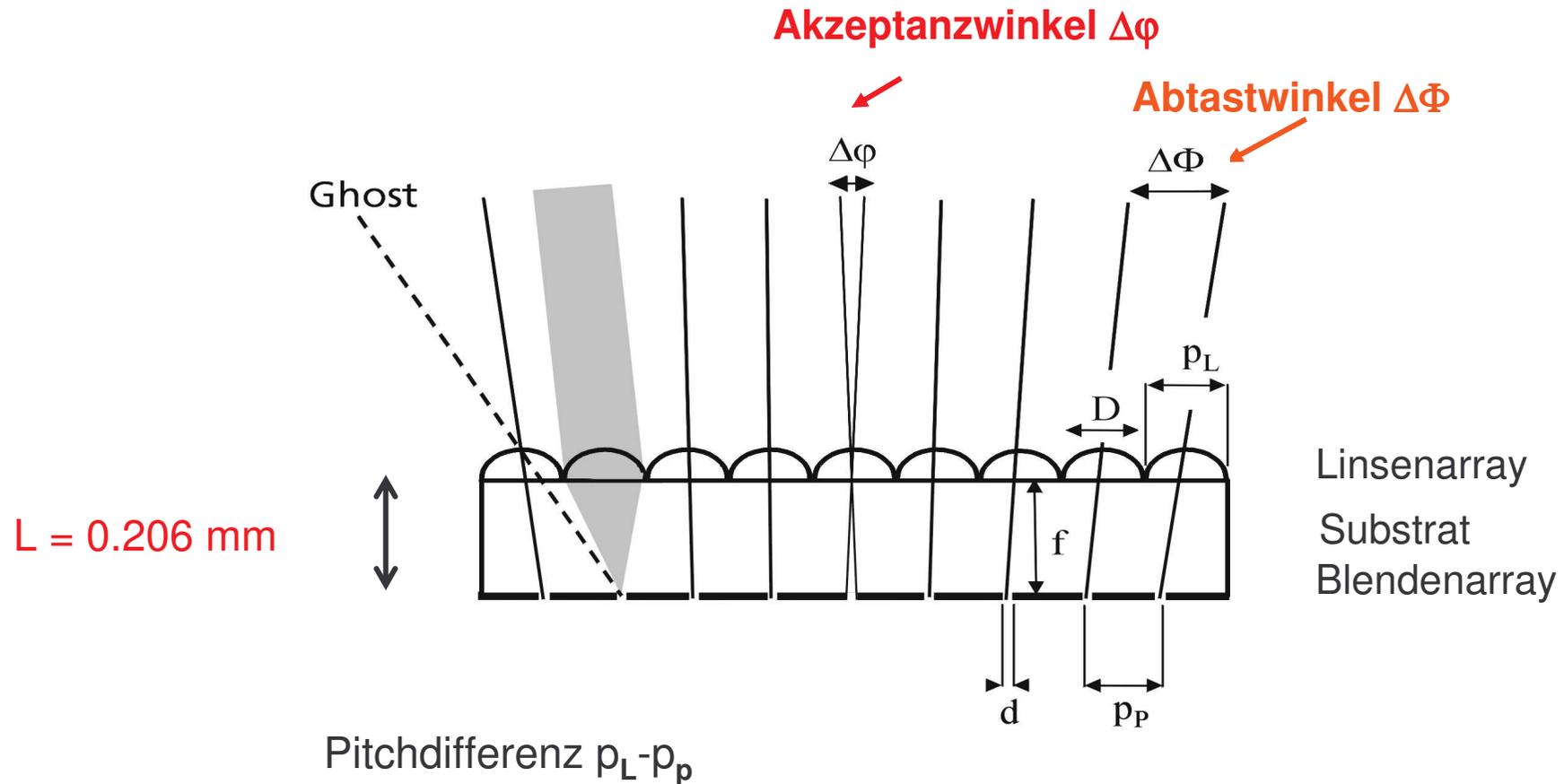
Natur:
Rezeptoren auf
gekrümmten Oberflächen

Technik:
Rezeptoren auf ebenen
Oberflächen →
Bildfeldwölbung

Natürliches Appositionsauge



Prinzip künstlicher Appositions-Facettenaugen



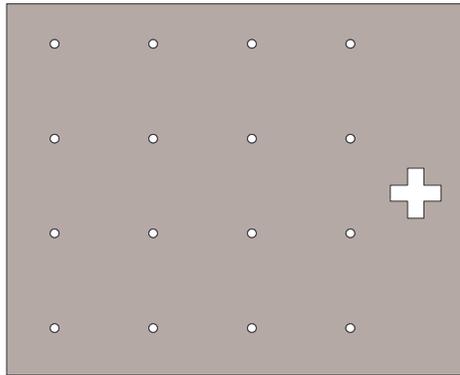
J. Duparré, P. Dannberg, P. Schreiber, A. Bräuer, and R. Völkel, "Bilderfassungssystem und dessen Verwendung," Pat. DE 10 2004 003 013.8 (2004).

Archivierungsangaben

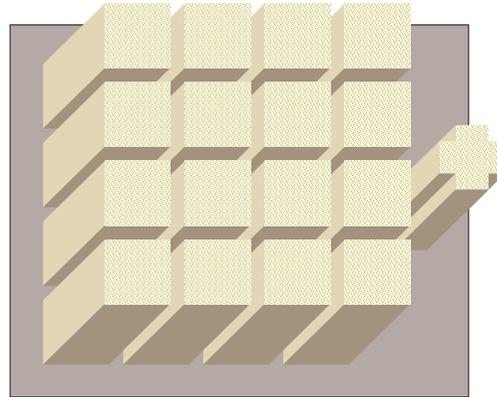
Seite 11



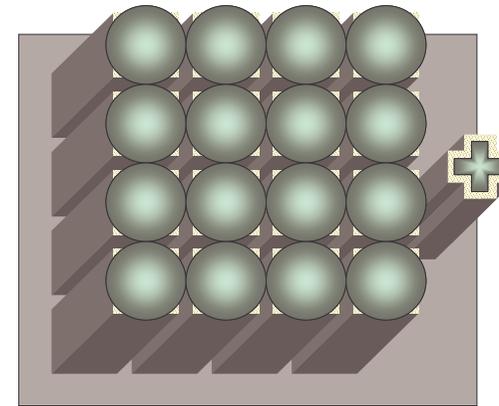
Herstellung optisch isolierter Kanäle aus Fotolack



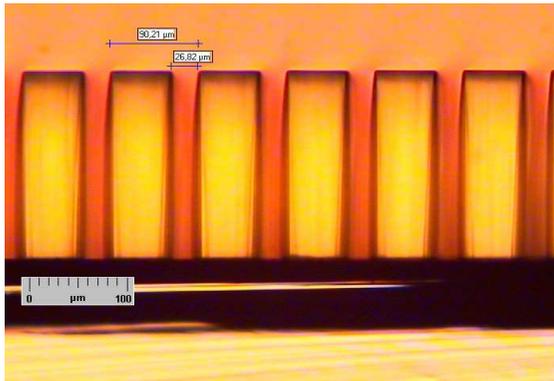
Metallschicht mit
Lochblenden auf
Substrat



SU8-Zwischenschicht,
lateral strukturiert

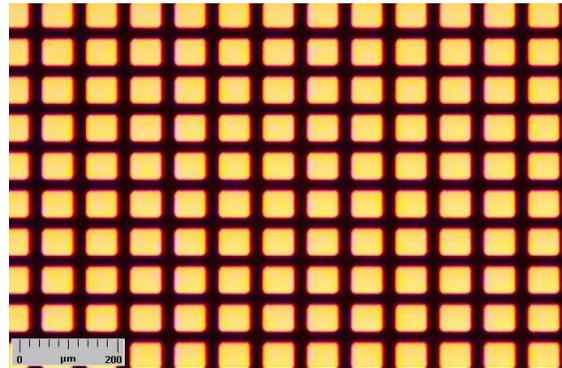


Gräben mit schwarzem Polymer ausfüllen,
Mikrolinsen abformen

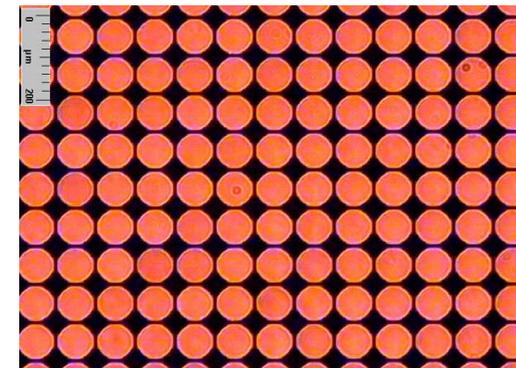


Seitenansicht der Türme

Archivierungsangaben



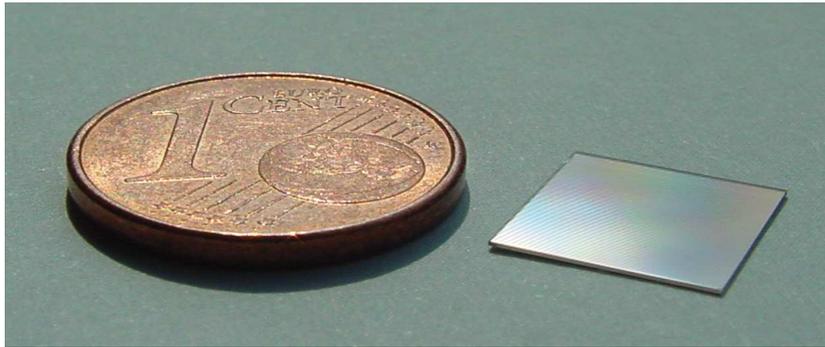
Gräben gefüllt



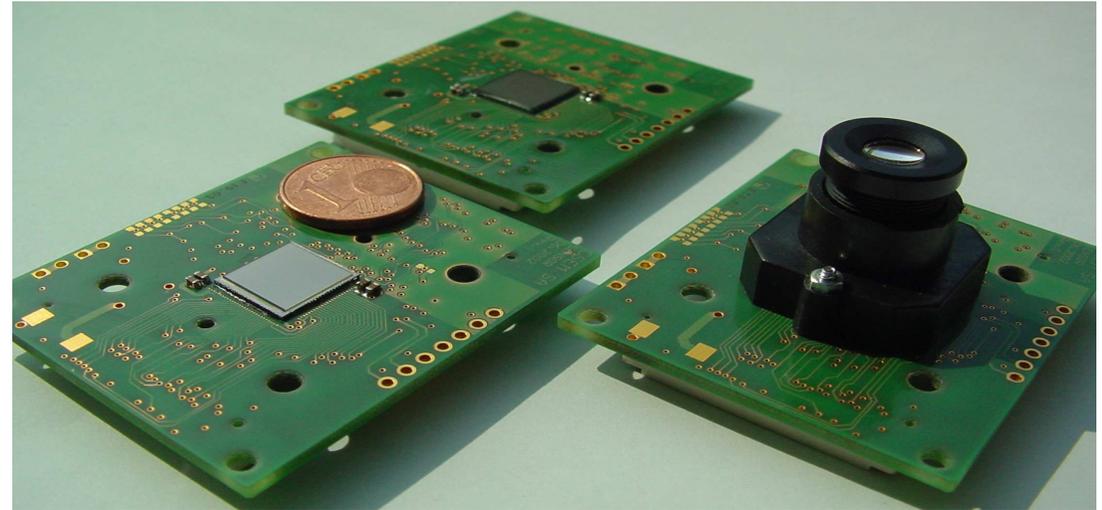
Mikrolinsen abgeformt



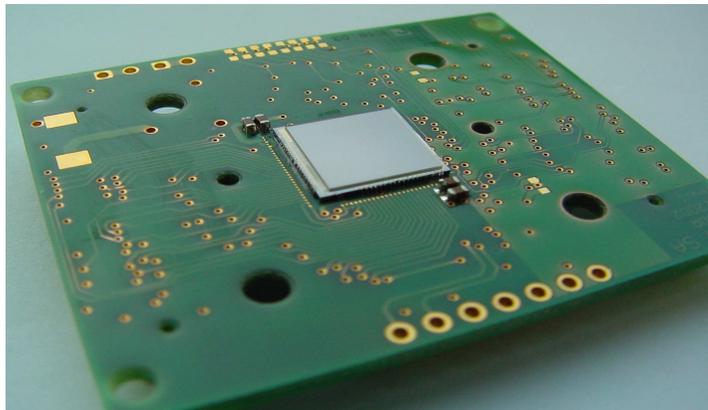
Objektiv und Kamera



Facettenaugen-Objektiv



Sensor-Board + Facettenaugen-Objektiv,
mit Standardobjektiv zum Vergleich



Sensor-Board + Facettenaugen-Objektiv

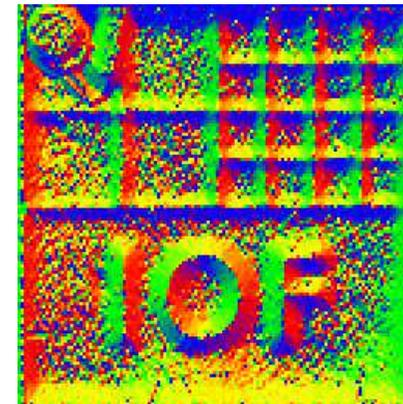
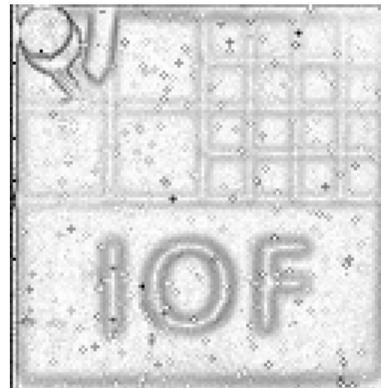
Sensor: CSEM Neuchâtel

Testbilder (keine Nachverarbeitung!)

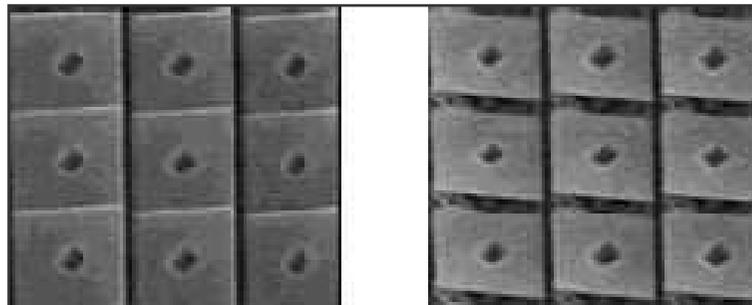
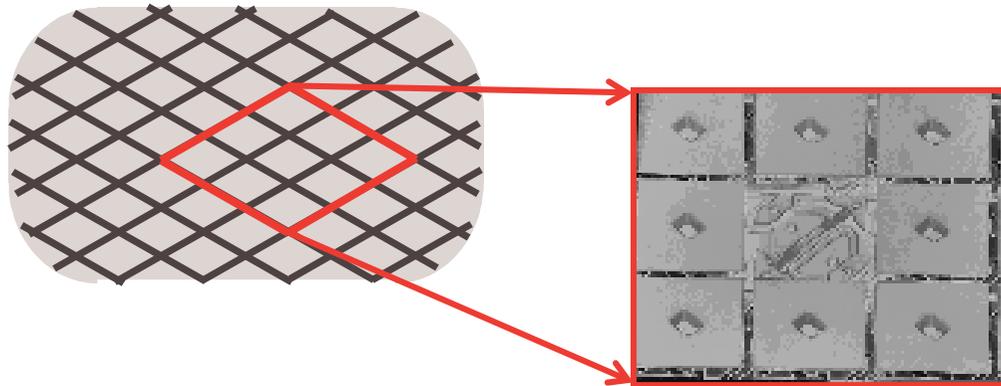
Gesichtserkennung:



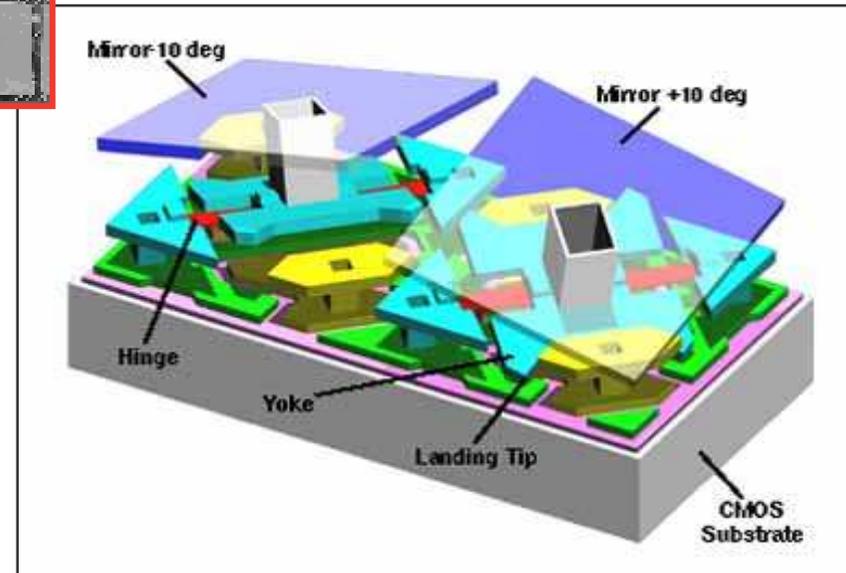
Möglichkeiten der Sensorausgabe:



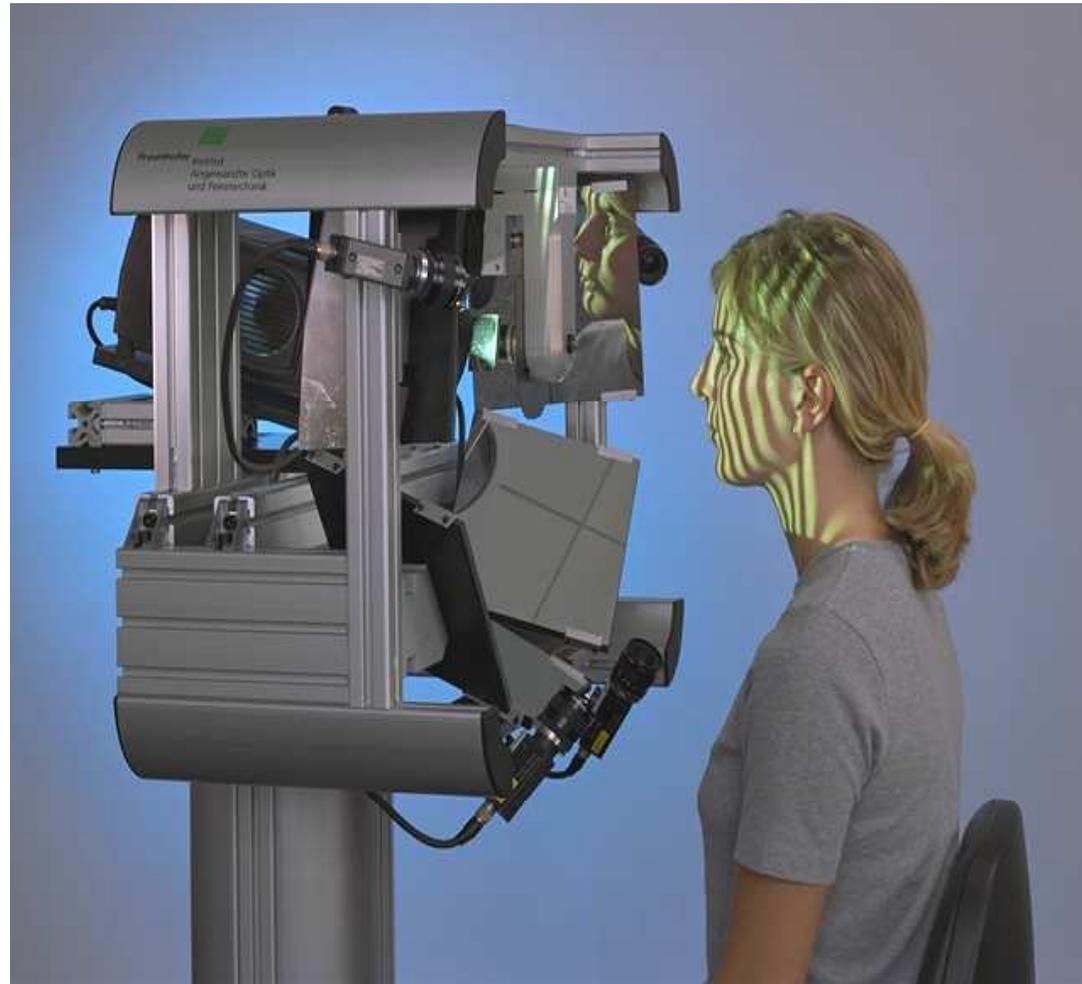
Reflektierende Mikrodisplays - DMD



Texas Instruments



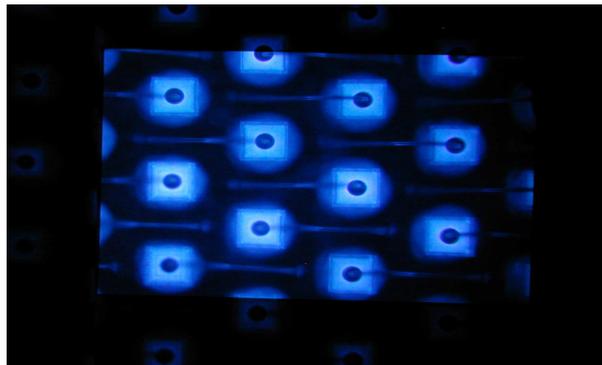
Gesichtsfeldscanner



LED - Beleuchtungssysteme



Head-up display (HUD, Siemens)



LED-Array
Blau
(Fa.OSRAM)

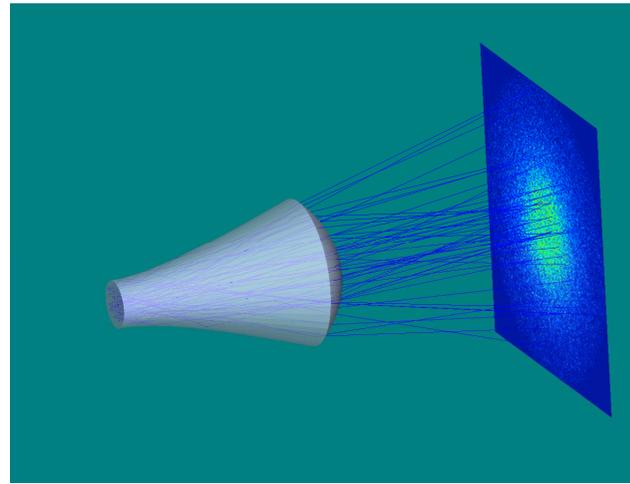
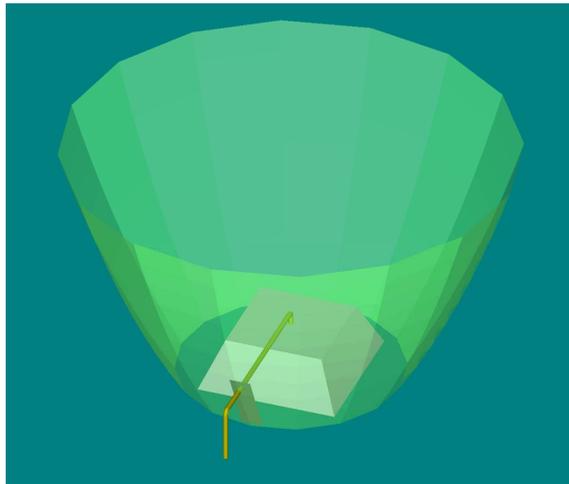


Mobiltelefon-Projektoren

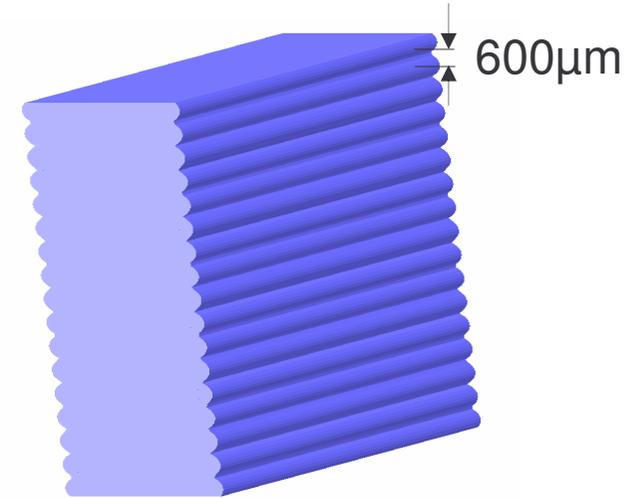
Photonen in Nutzrichtung bringen !
=> Primär- und Sekundäroptik



LED - Beleuchtungssysteme



+



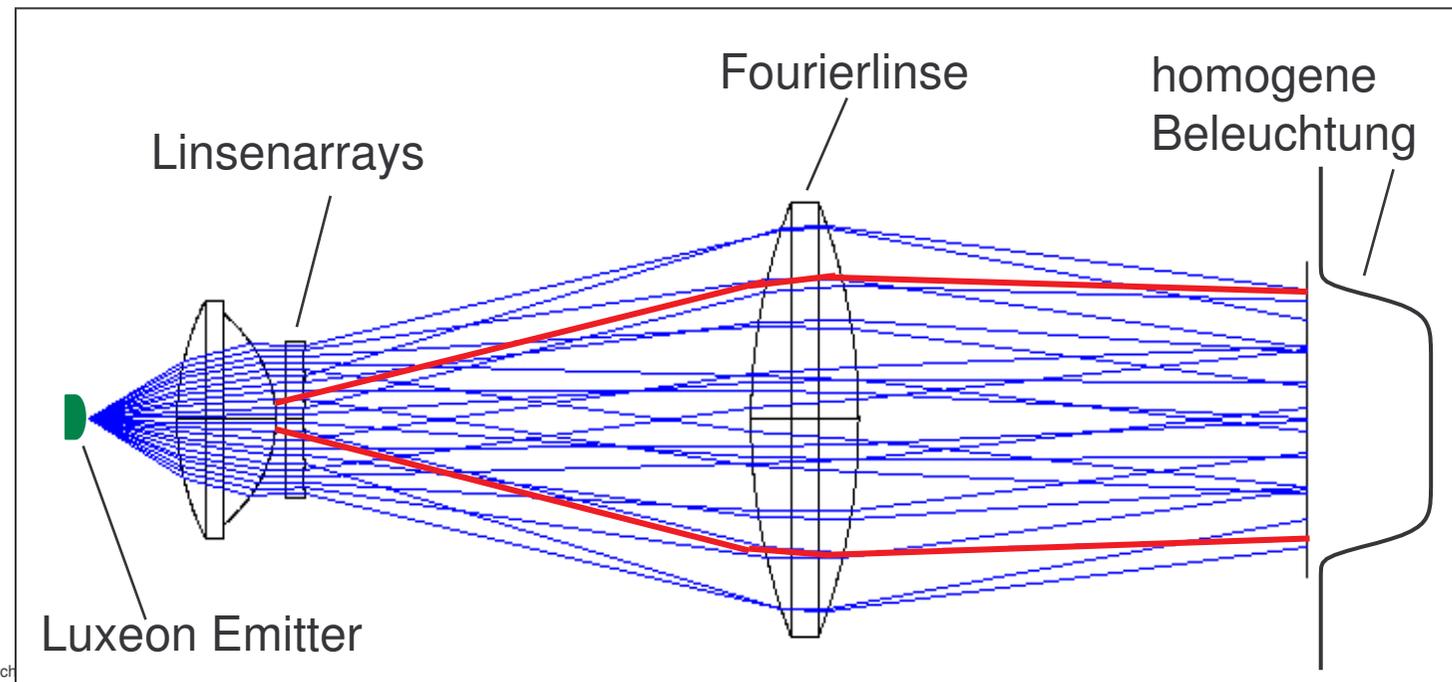
Primäroptik: Lichtkonzentrator: Länge 3 mm =>
80% Intensität in $\pm 20^\circ$
Nacktchip <10%

Sekundäroptik
Lithografie + Ätzen (z.B.)

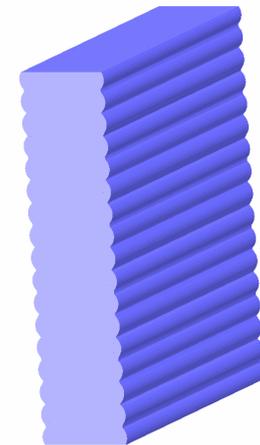
Problem: Herstellung der Lichtkonzentratoren im (Wafer-) Array,
lithografisch nicht möglich

Homogenisierung von LED-Strahlung

Ansatz: Miniaturisierung durch Verschachtelung von Homogenisierung und Farbkombination



Tandem-Linsenarrays



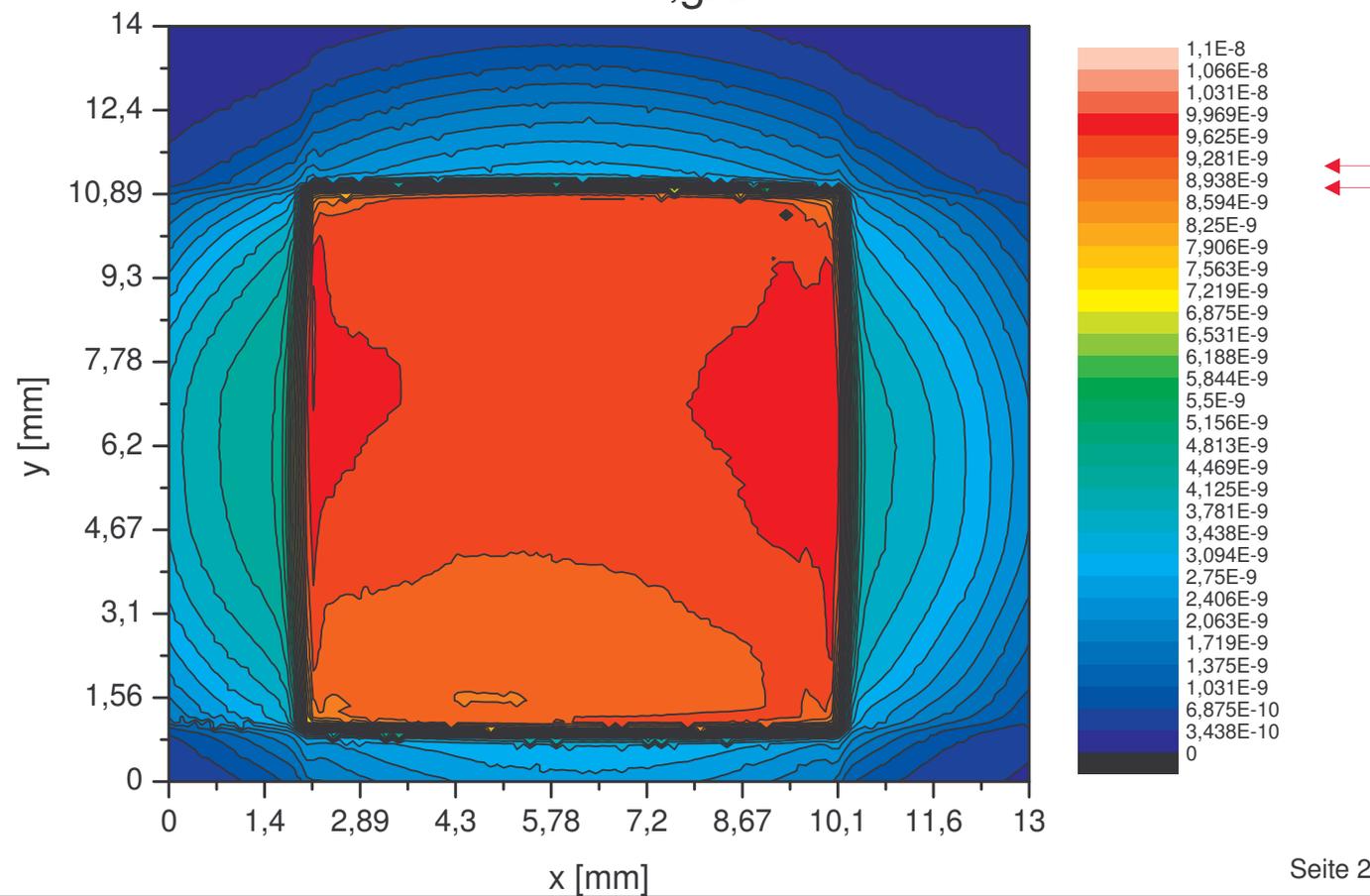
Pitch 0.46 / 0.6mm
Substratdicke 2mm
Füllfaktor 99%



Fraunhofer Institut
Angewandte Optik
und Feinmechanik

LED-Homogenisierung - Messung

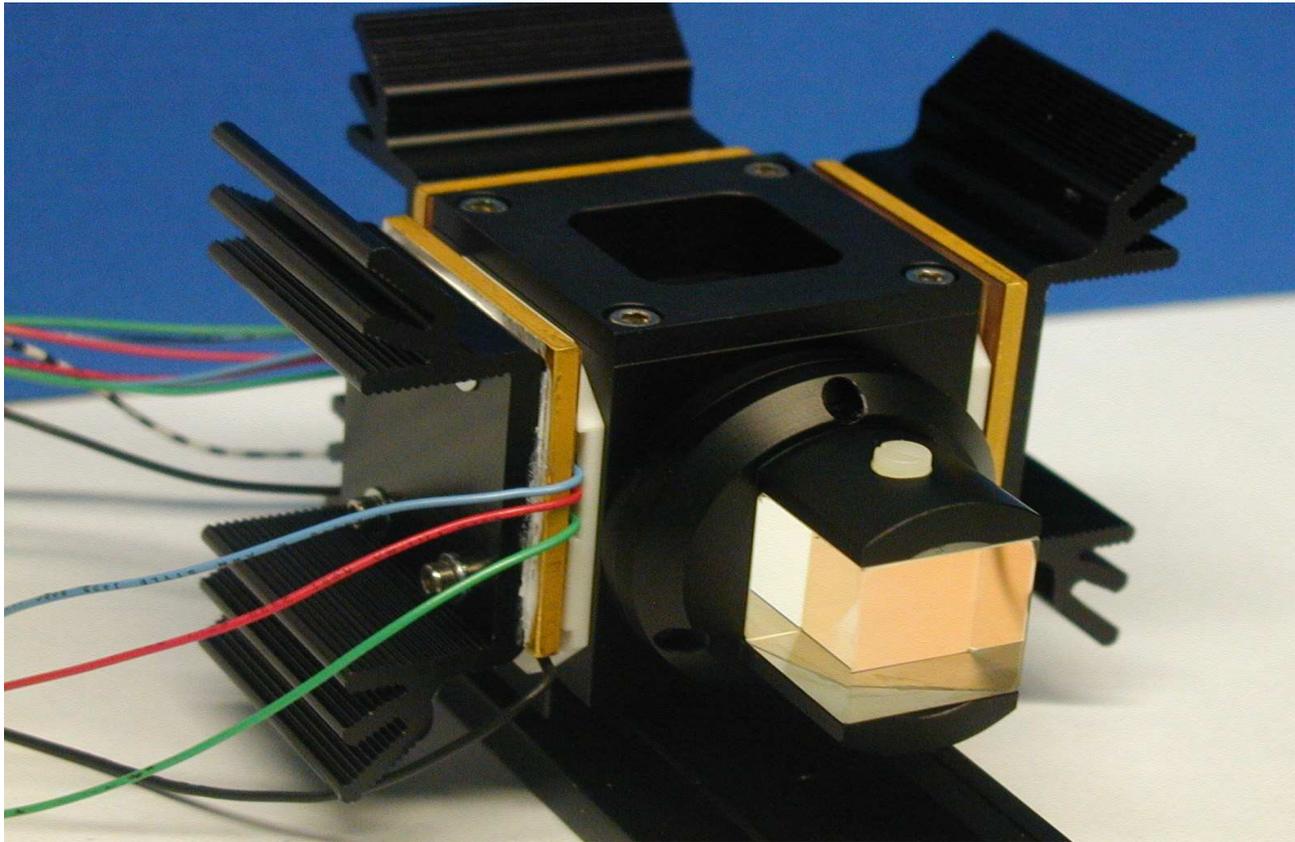
Luxeon LED, grün



Besser 5% p.v.
über 8x8 mm²



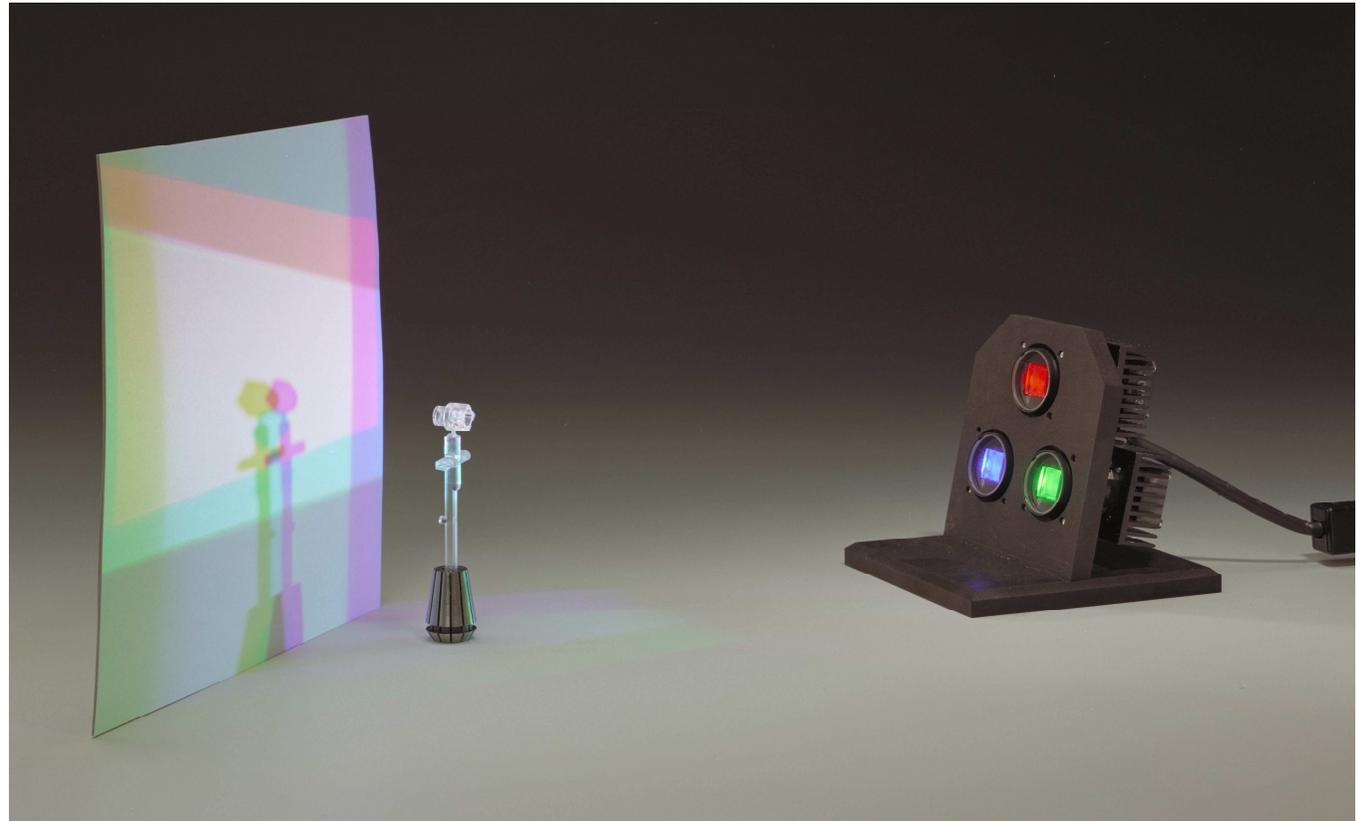
3-Farben LED-Modul für Beleuchtungsanwendungen



Weißlichterzeugung durch homogenisierte RGB LED-Strahlung

Luxeon-LED (RGB)
Tamdem-Linsenarrays

Homogenisierung
besser 5% p.v.



Mikrooptik-Modul: 7 mm lang



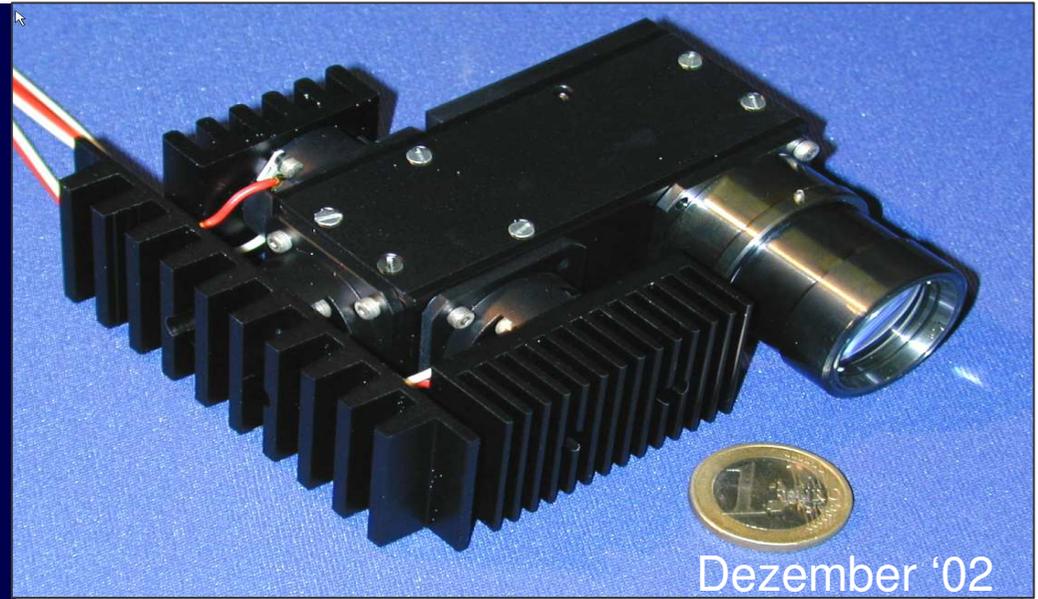
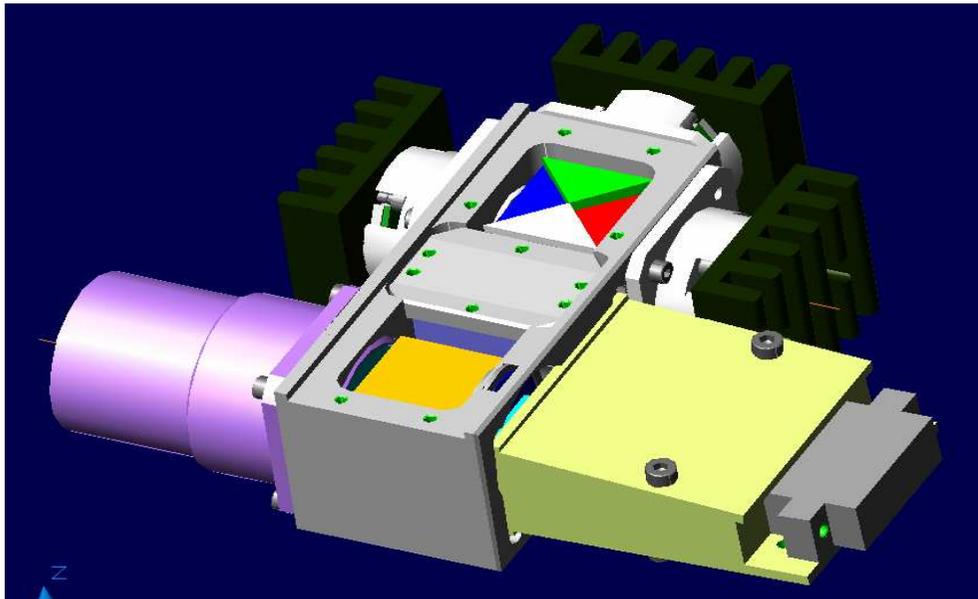
LCoS-Projektor mit LED's

DigiPro

- Luxeon-LEDs
- kompaktere Bauform
- angepasste Optikkomponenten (ColorCube, Polteiler)
- angepasstes Objektiv (Zeiss)

LCoS-Projektor (Konstruktion)

LCoS-Projektor (Beleuchtungseinheit)



Fraunhofer Institut
Angewandte Optik
und Feinmechanik

Pocket Imager

LCoS basiert



Carl Zeiss Jena GmbH

SVGA (800 x 600)

Masse: < 450 g

Helligkeit: > 25 lm

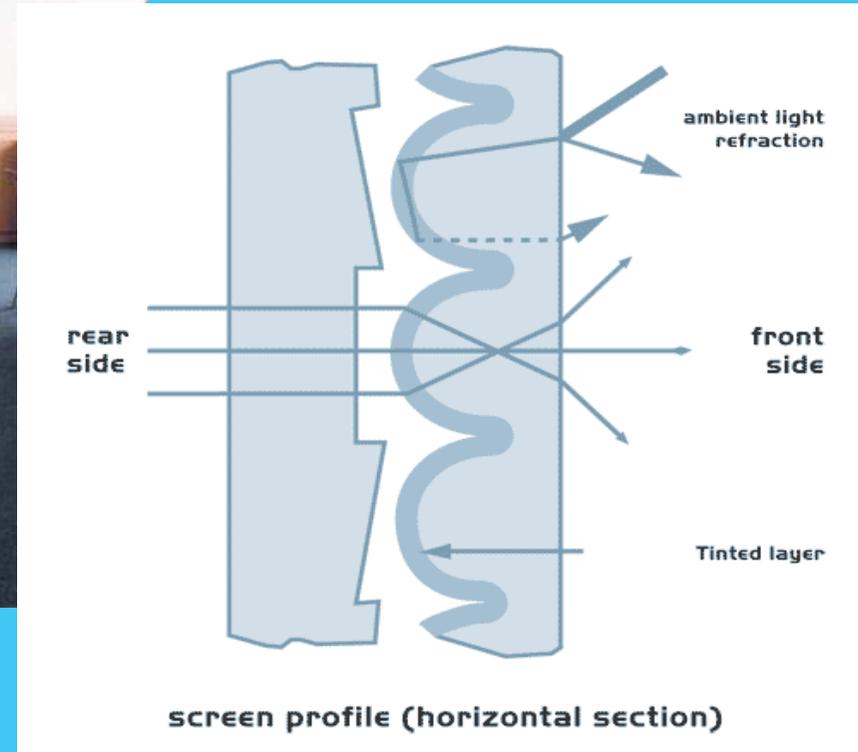
Leistungsaufnahme: < 30 W

Akku-Laufzeit: > 2 h





dnp denmark



Hinterleuchtungstechnik

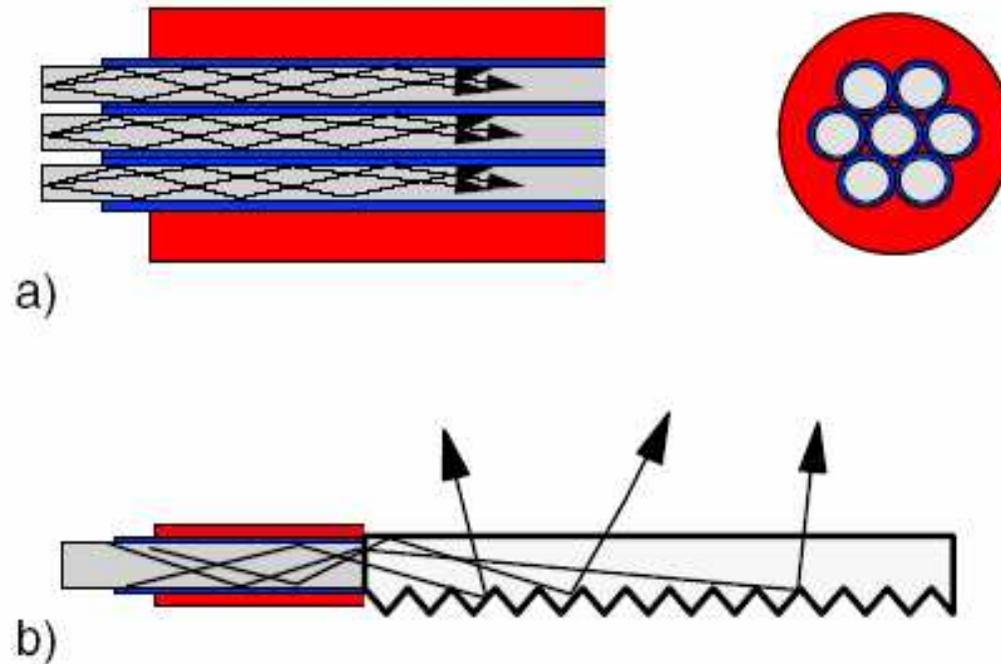


Abb.1a,b: Lichtleitung im Faserbündel (oben) und massiven Lichtleiter (unten)

Ringbeleuchtung (PKW)

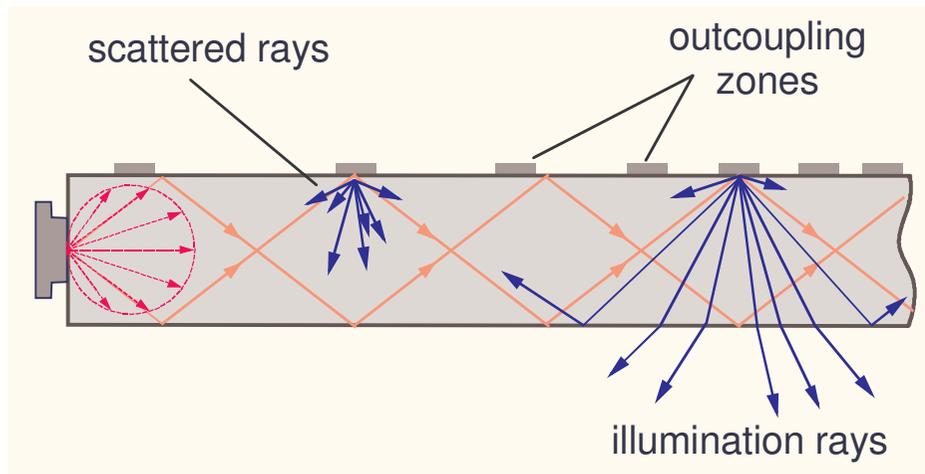


C.Lüder DGaO-Proceedings 2004

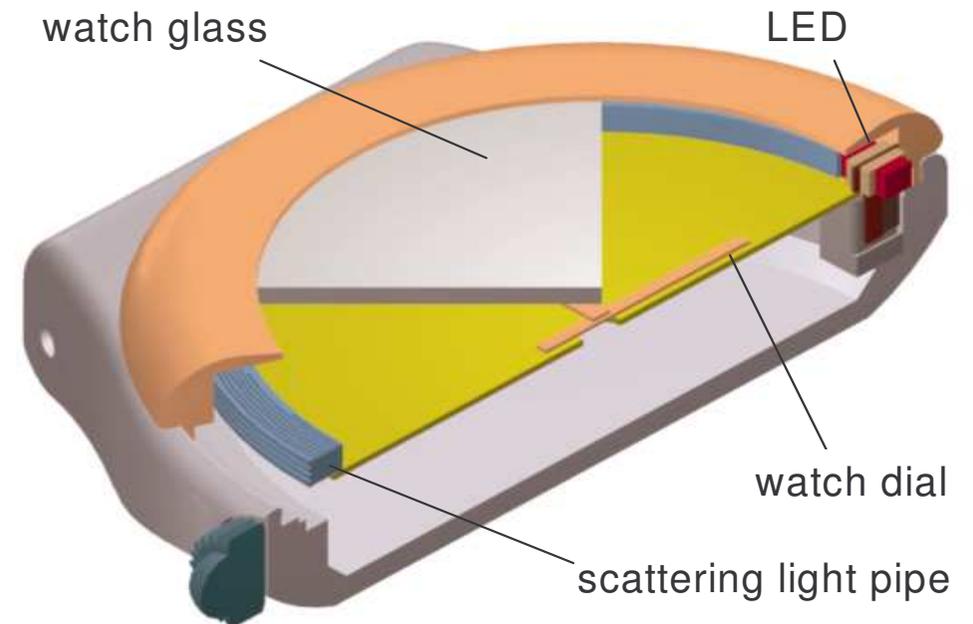
Abb.4: Lichtleitringe als Positionslicht, versorgt mittels flexibler Lichtleiterbündel



Illumination light pipes



Europ. Patent EP860755A1 (1998)
Europ. Patent EP99109018.4 (1999)



Archivierungsangaben



Fraunhofer Institut
Angewandte Optik
und Feinmechanik

TFT-LCD Hinterleuchtung



Figure 20: 17" TFT-LCD with RGB backlighting

OSRAM Opto Semiconductors 2004

Archivierungsangaben

Seite 29



Fraunhofer Institut
Angewandte Optik
und Feinmechanik

Mikrooptische Module für Halbleiterlaser(arrays)

Laser:

Emitterbreite: 100 ... 200 μ m
 Leistung: mW ... 50W CW
 Wellenlänge: 635 ... 980nm

Abstrahlung:

fast axis Singlemode, Gauss
 Divergenz 25 ... 40° FWHM
 slow axis Multimode, Top-hat
 Divergenz 5 ... 15° FWHM

Laserarrays:

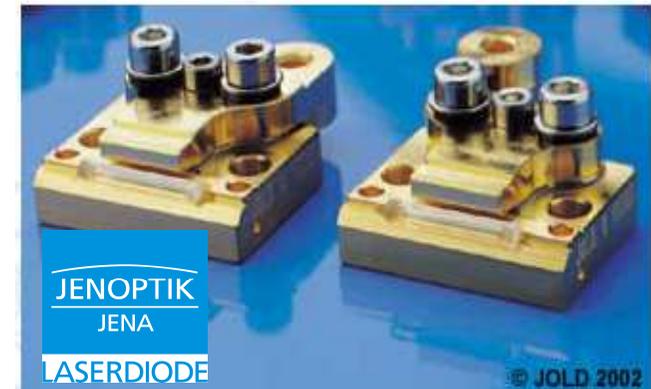
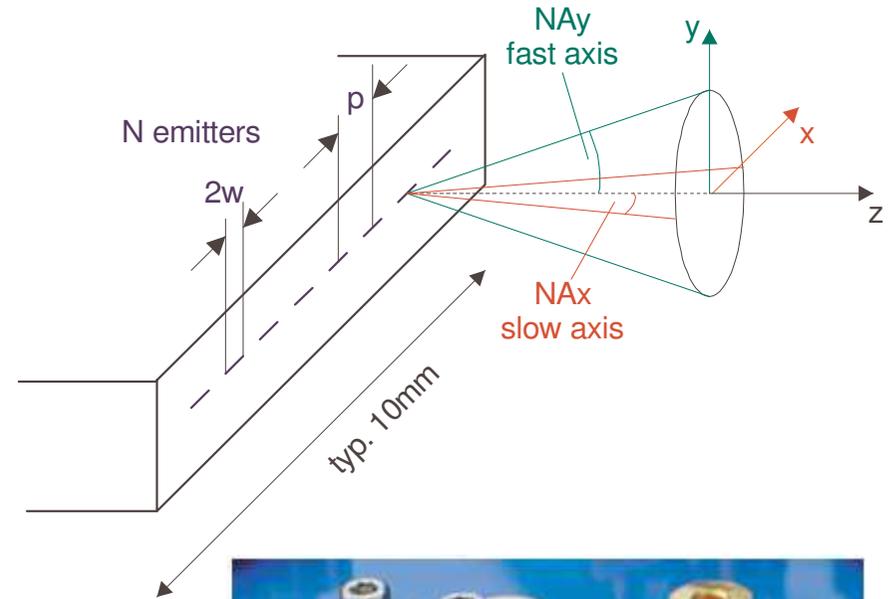
Emitterpitch: 200 ... 500 μ m

Mikrooptische Module für Abbildung der Laser(arrays)

auf LL-Faser oder Digital Imager (LCoS, DMD)

Strahlformung zu zirkularer Intensitätsverteilung

(Gauß, Top-hat)



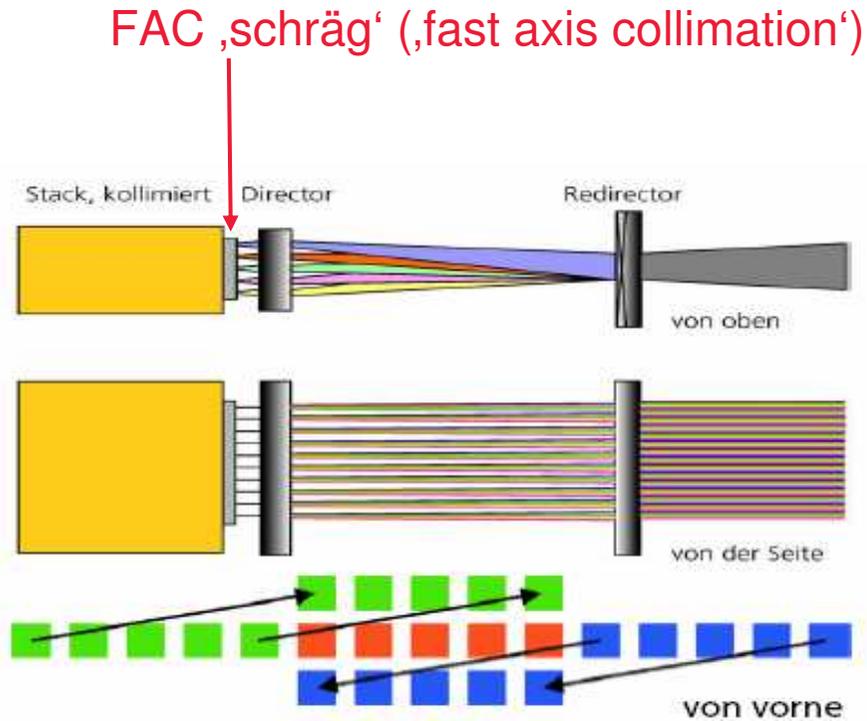
Archivierungsangaben



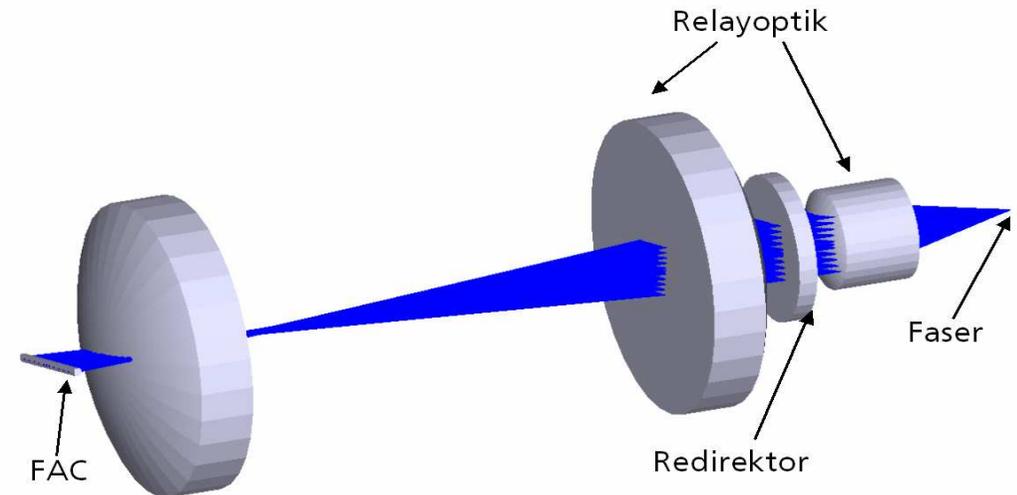
Fraunhofer
 Institut
 Angewandte Optik
 und Feinmechanik

Strahlformung durch Schrägstrahlabbildung

Prinzip



Design

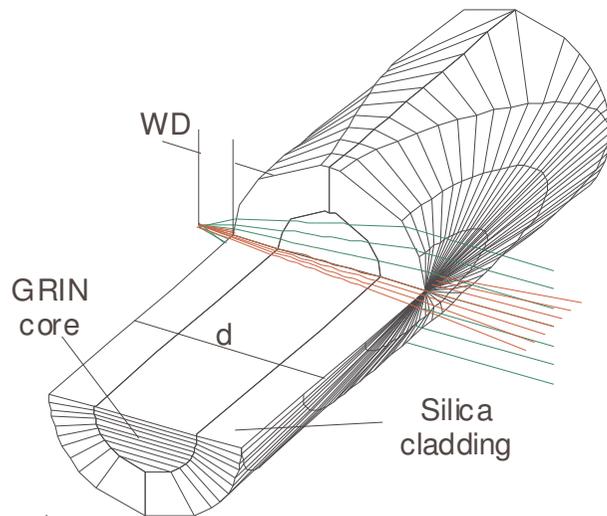


Strahlformung mit Schrägstrahlabbildung

Mikrooptische Elemente

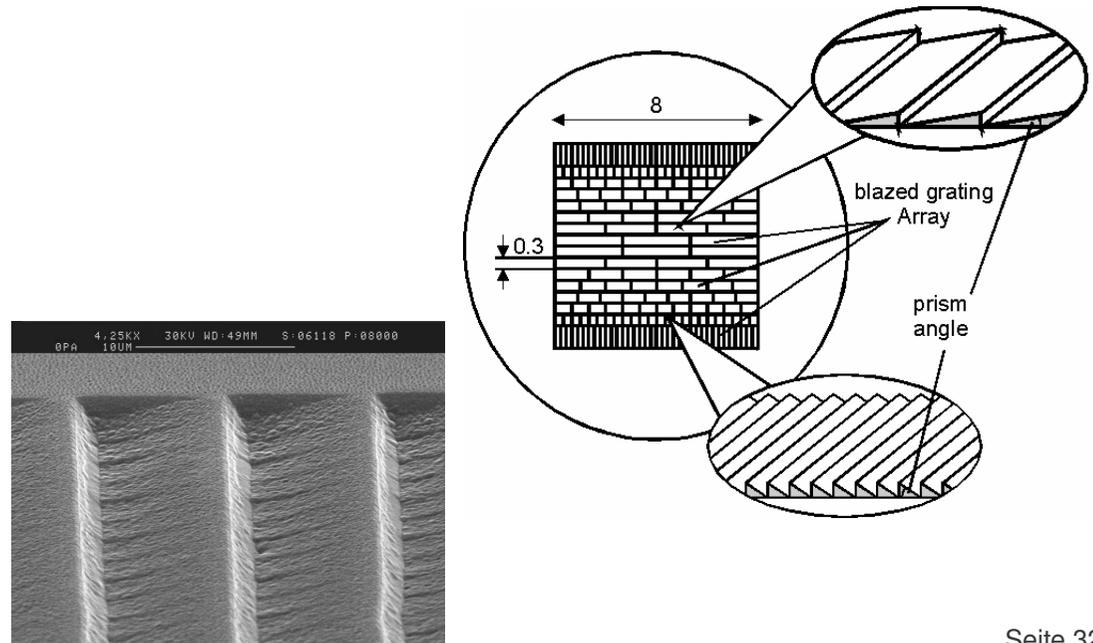
FAC (fast axis collimation)-Linse

hohe NA
keine off-axis Aberrationen ($5...10^\circ$)
montiert mit sub- μm Präzision



Präzise Redirektor-Prismen

Array geblazter Gitter \gg Beugungseffizienz optimiert



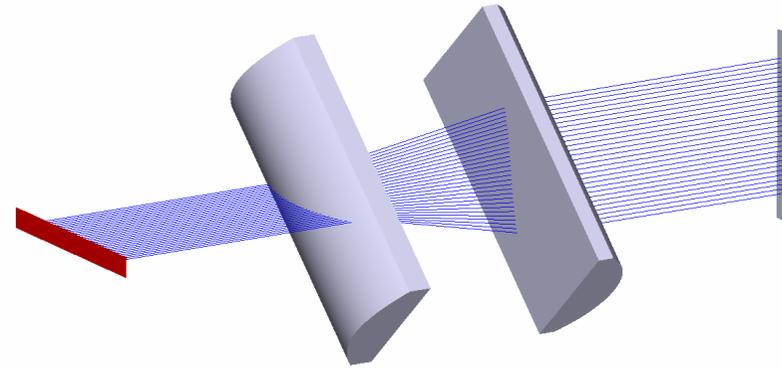
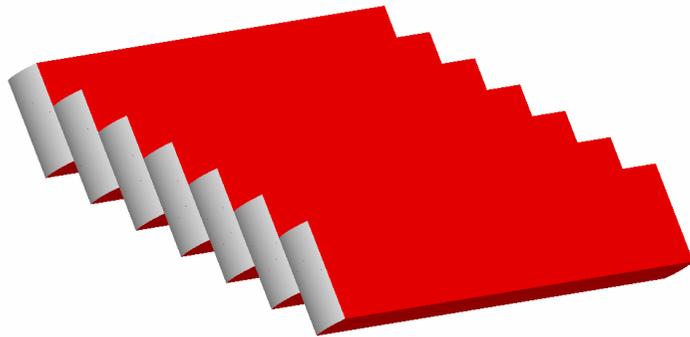
Strahlformung mit Beam Twister

IOF (Projekt NOVALAS)

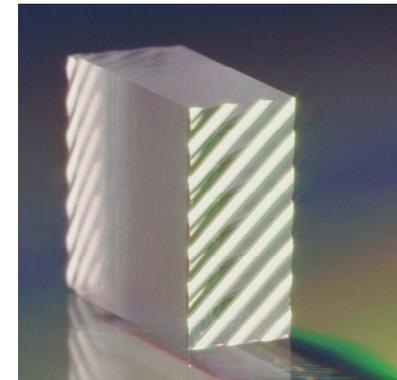
Wirkprinzip:
Zwei 45° geneigte Zylinderlinsen
in 2f Abstand



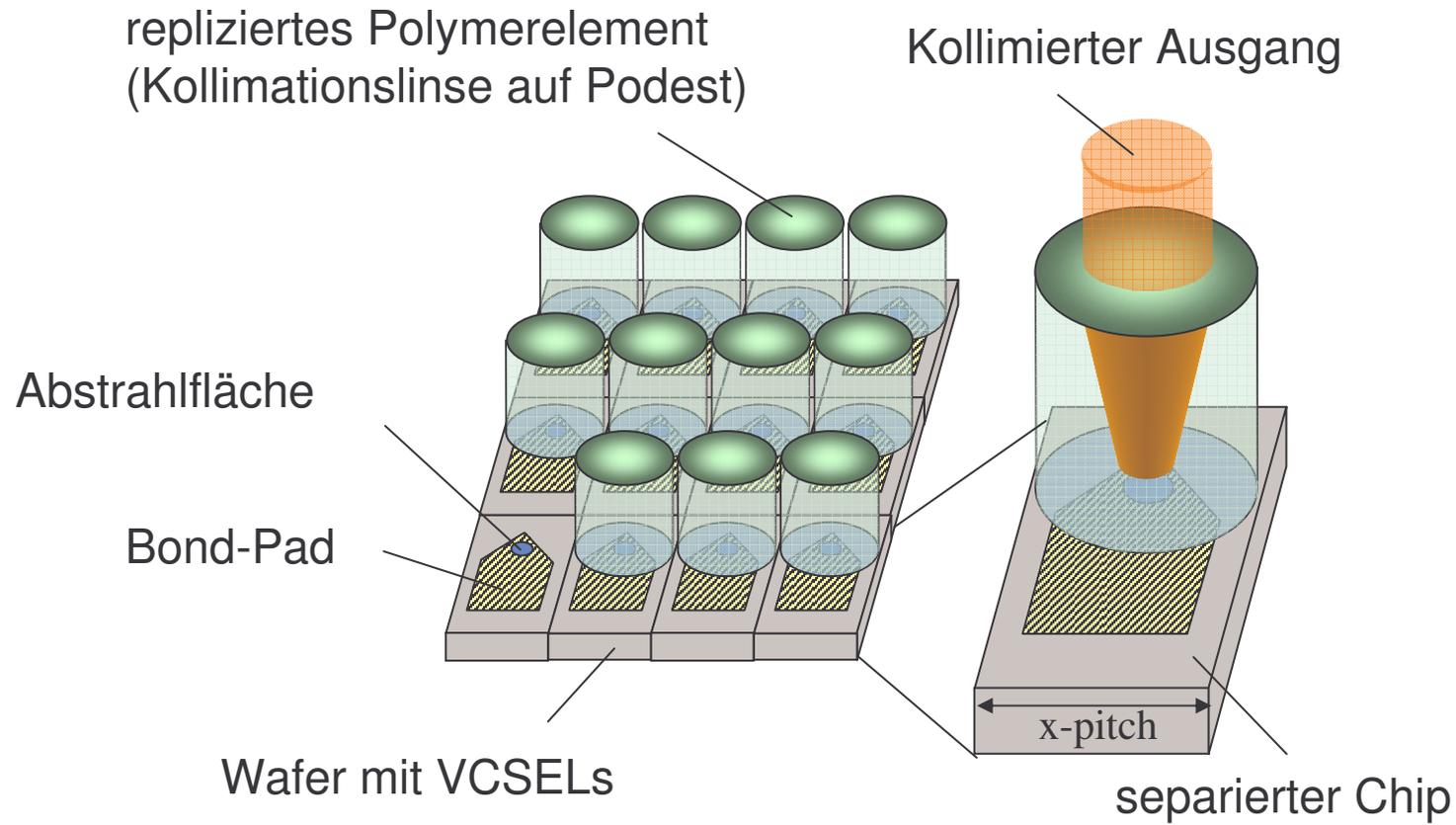
Array (N-Emitter)



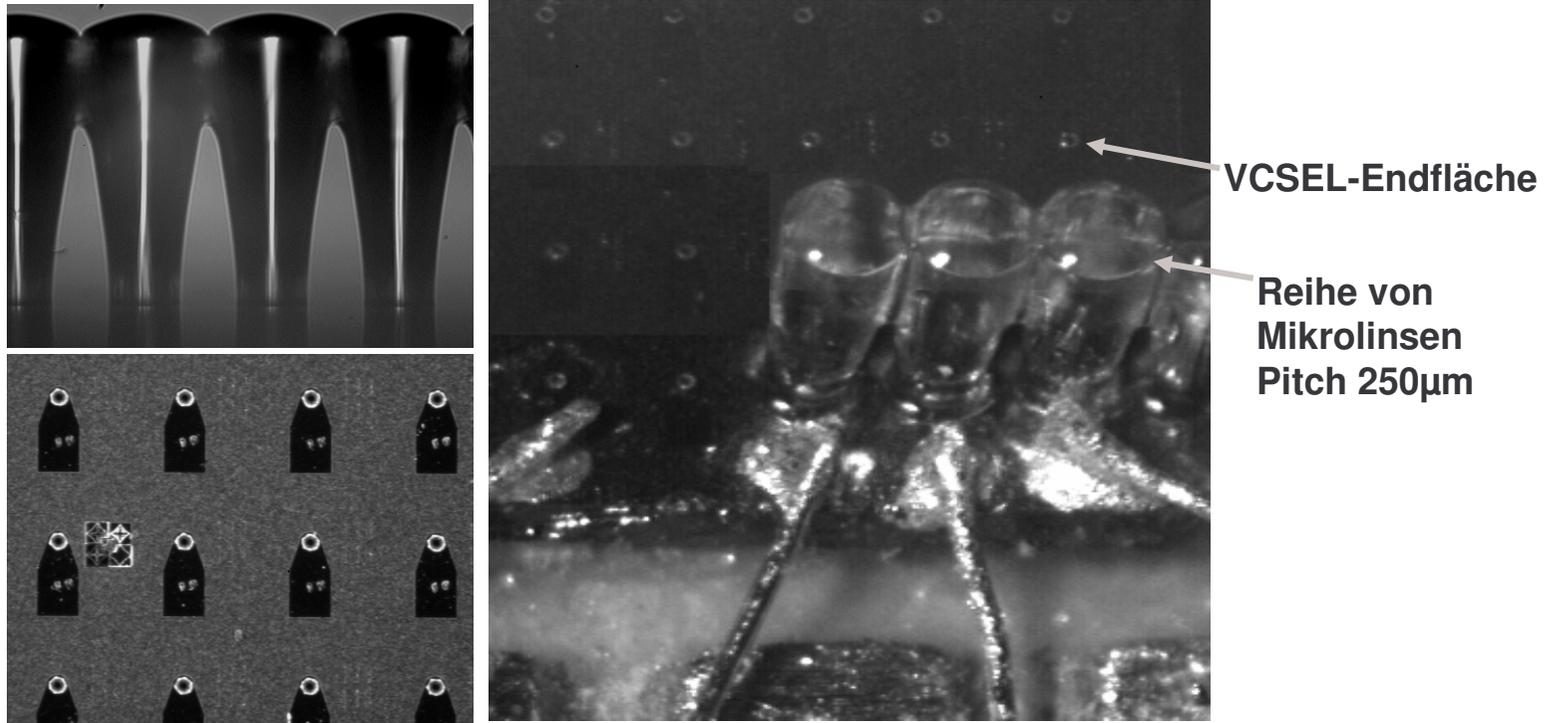
Realisierung:
Sphärische Reflowlinsen, zweiseitig
abgeformt



Wafer-scale-VCSEL-Kollimation



Linsenarray auf VCSEL

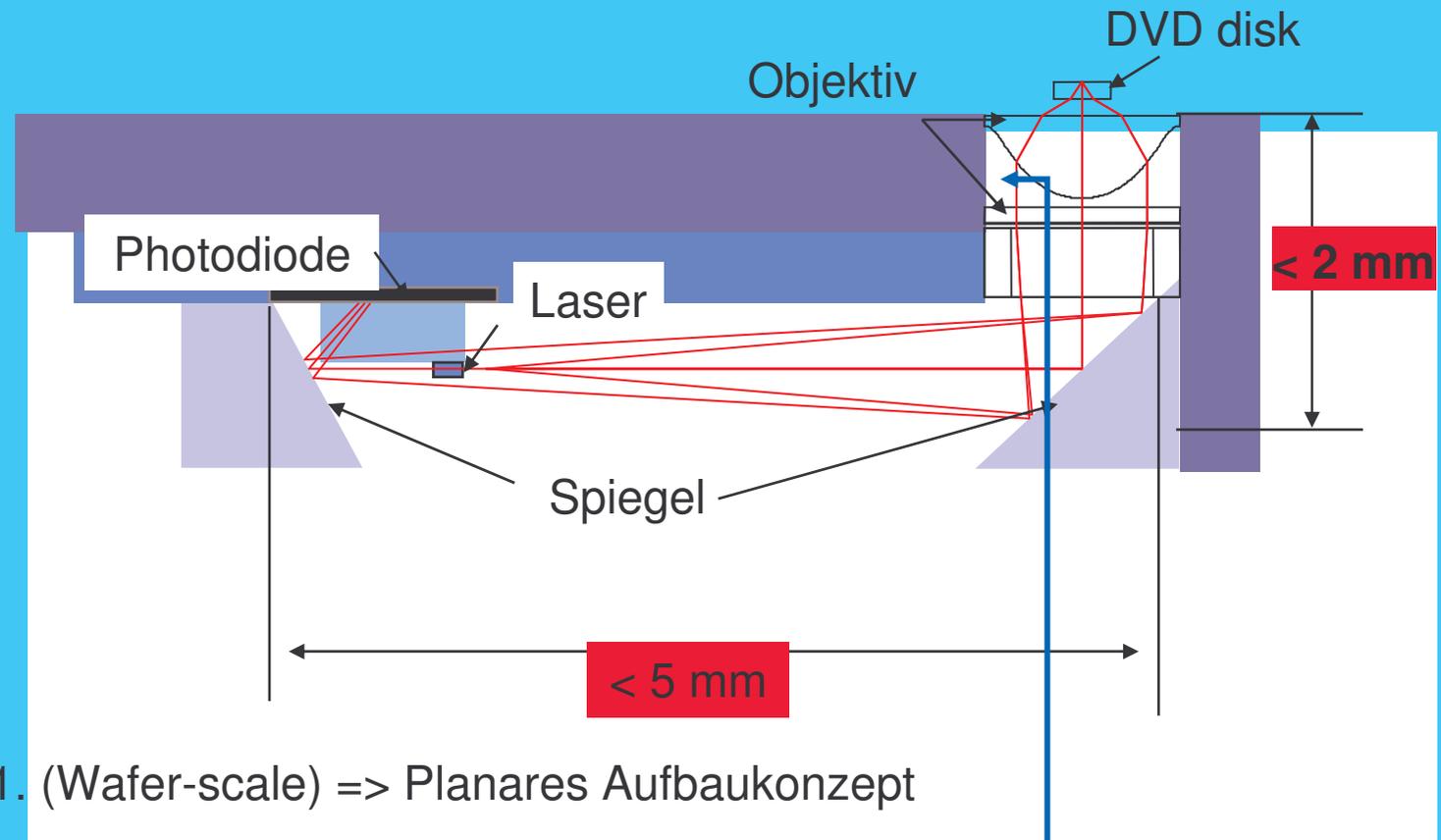


$R_c = 240\mu\text{m}$, Höhe der Polymerstruktur = $750\mu\text{m}$
berechnete Bündeldivergenz $\sim 1^\circ$



Tendenzen – DVD Pickup → Hybride Mikrooptiken

Volumenreduktion



Tendenzen:

1. (Wafer-scale) => Planares Aufbaukonzept
2. **Hybride Mikrooptik-Elemente**

Hybride Mikrooptik für DVD Pickup

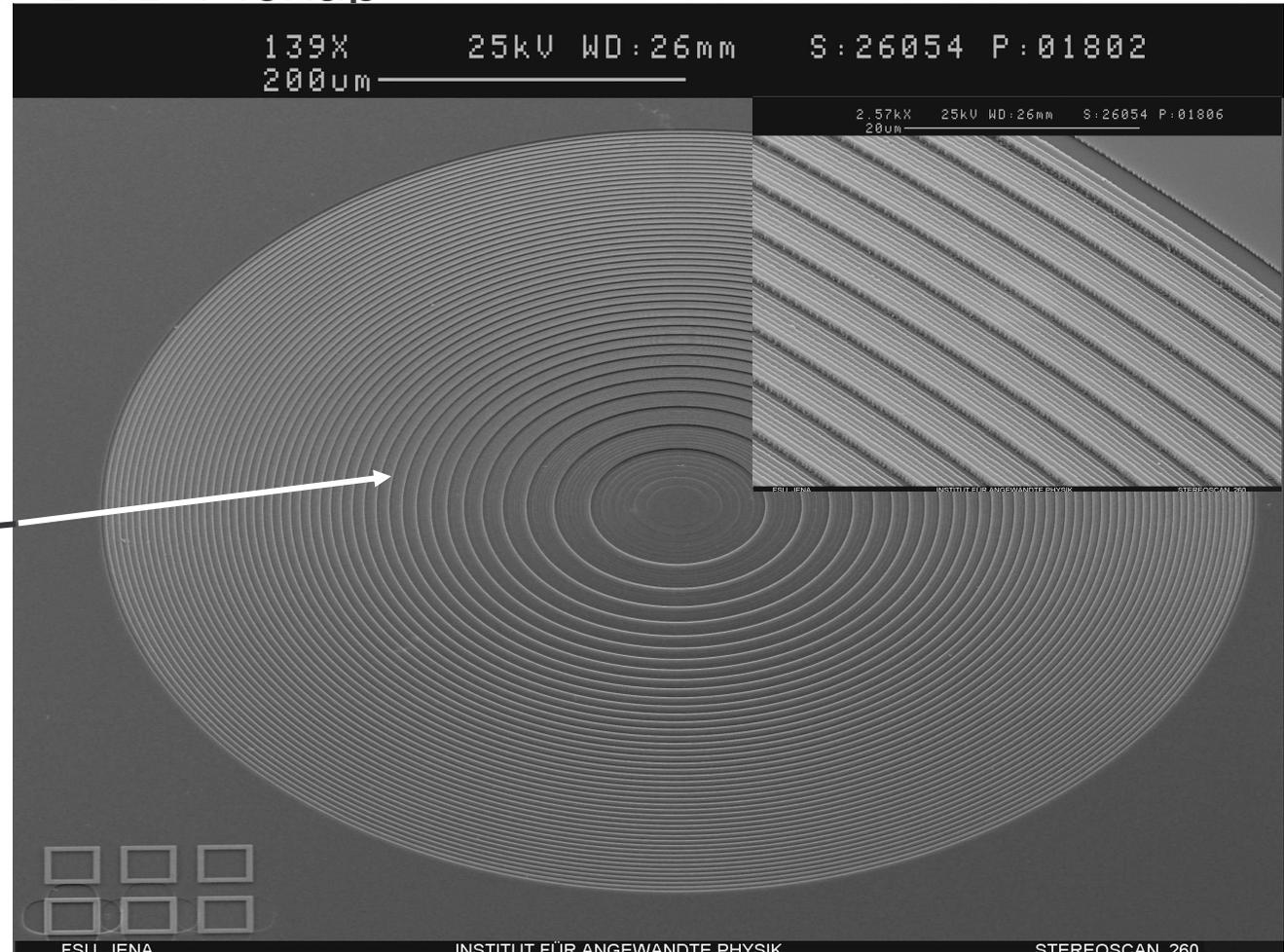
Quarz

Beispiel
Frontlinse
 $\lambda = 404 \text{ nm}$

DOE

Beugungseffizienz 85,4 %

(Resultat
Kley (IAP), Zeitner (IOF))



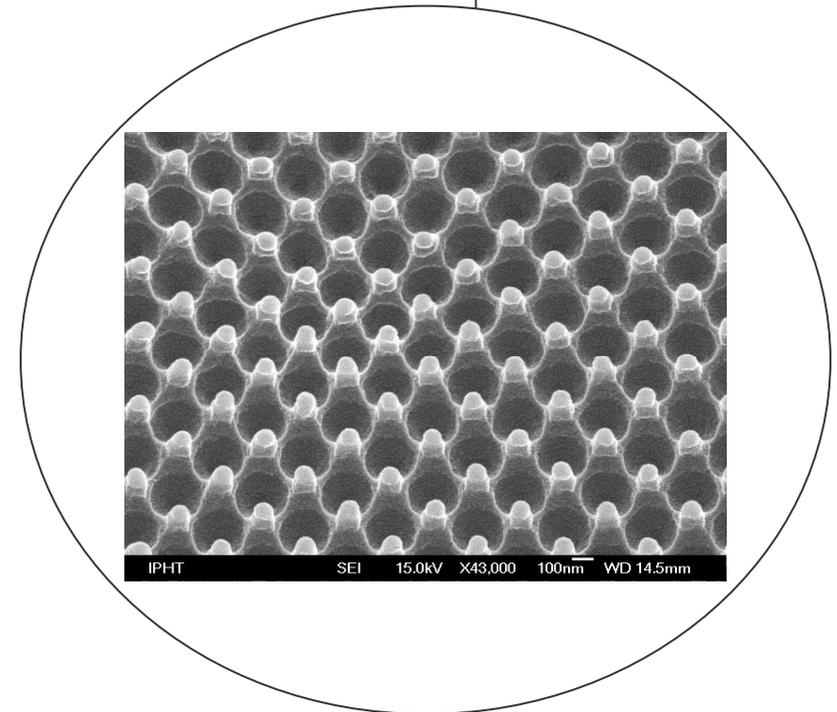
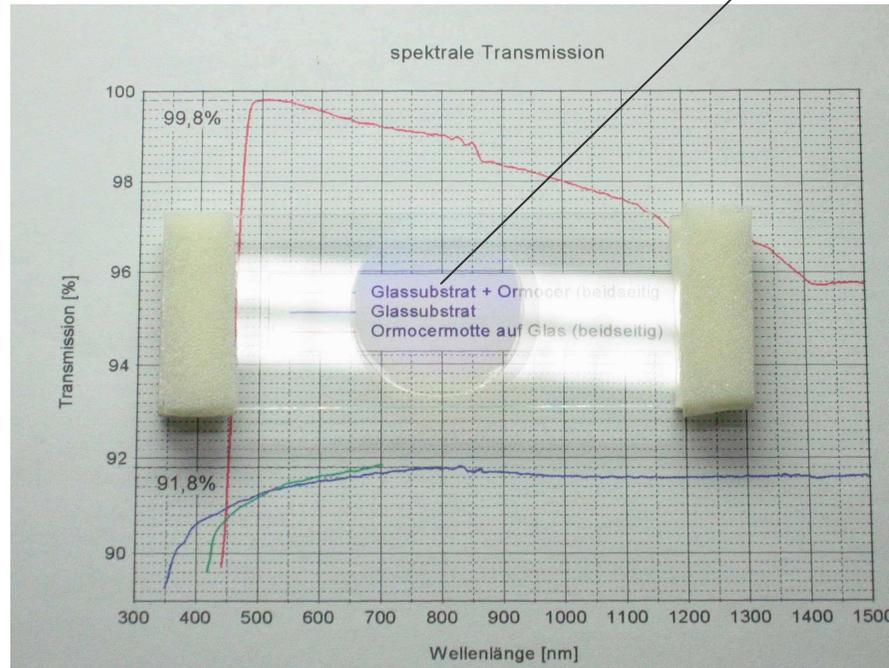
A

Seite 37



Fraunhofer Institut
Angewandte Optik
und Feinmechanik

Nanostrukturen (Ormocer-Replikation) zur Entspiegelung



AR- Mottenauge

Entspiegeltes Gitter in Quarzglas

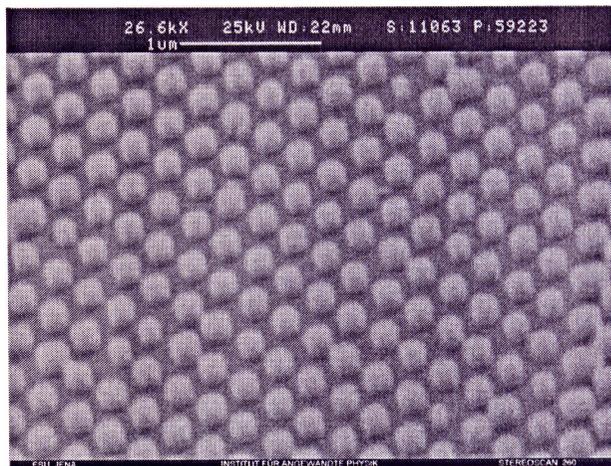


Fig.2: SEM-picture of binary dots

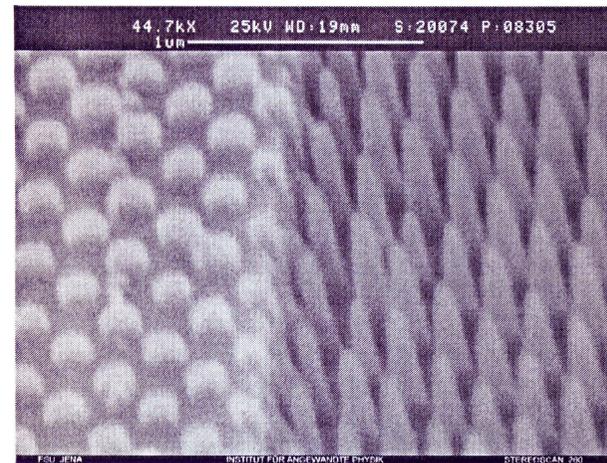


Fig.4: SEM-picture of fabricated gratings



Erhöhte Auskopplung aus LED

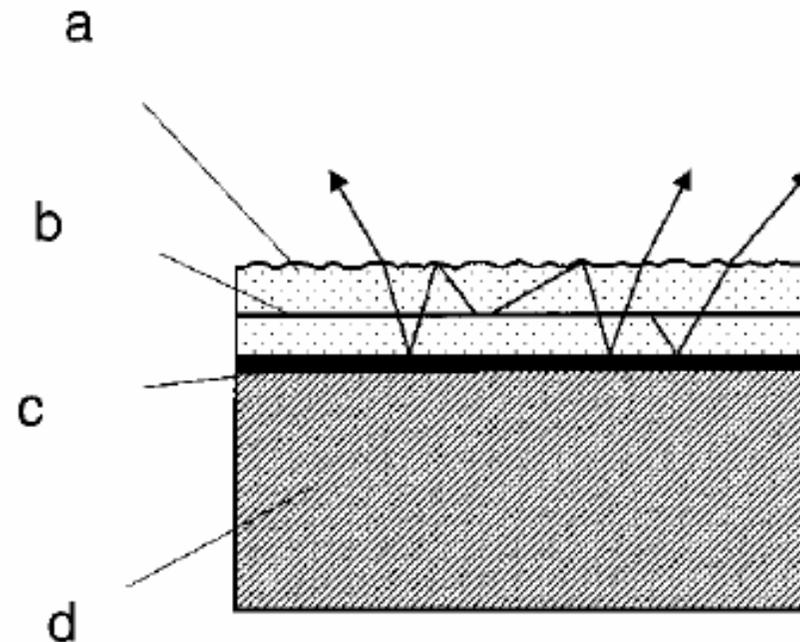
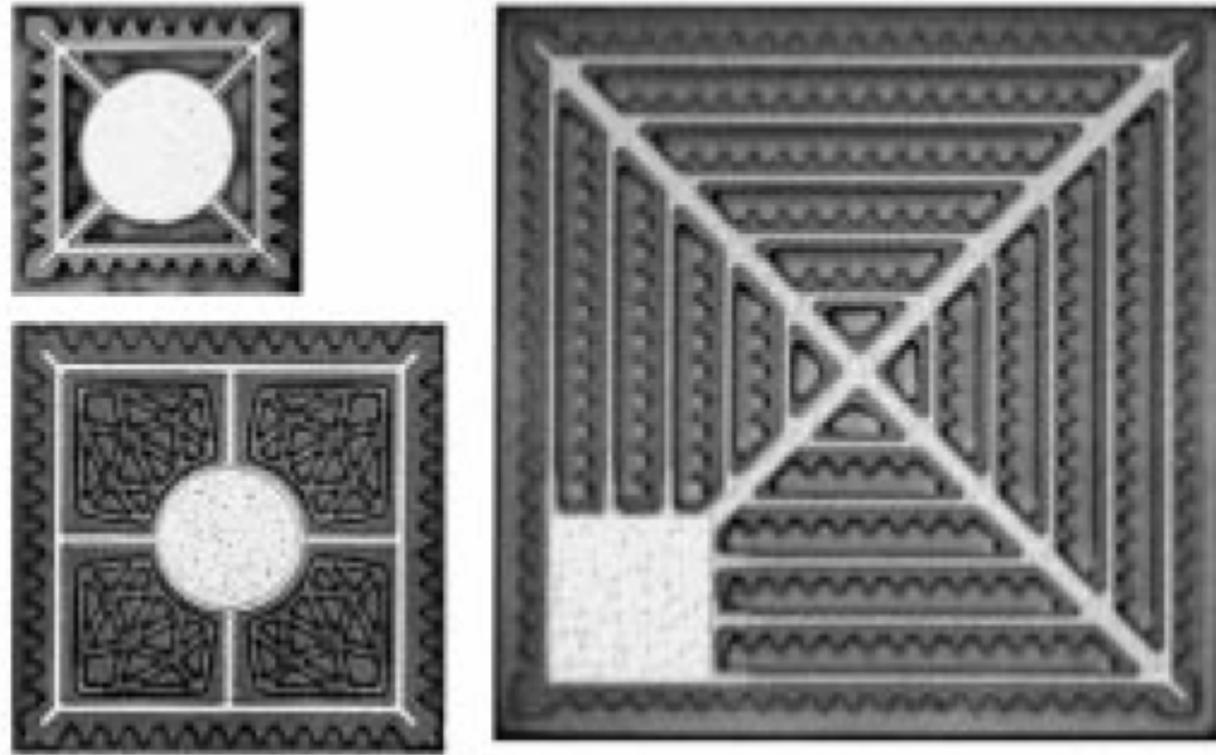


Fig. 8. Principle of operation of an LED with metallic reflector. (a) Rough surface, (b) thin active layer, (c) metallic mirror, and (d) carrier.

LED-Auskoppeloberflächen



K.Streubel et al. IEEE J

Selct.Top.QE 8 (2002) p 321 ff

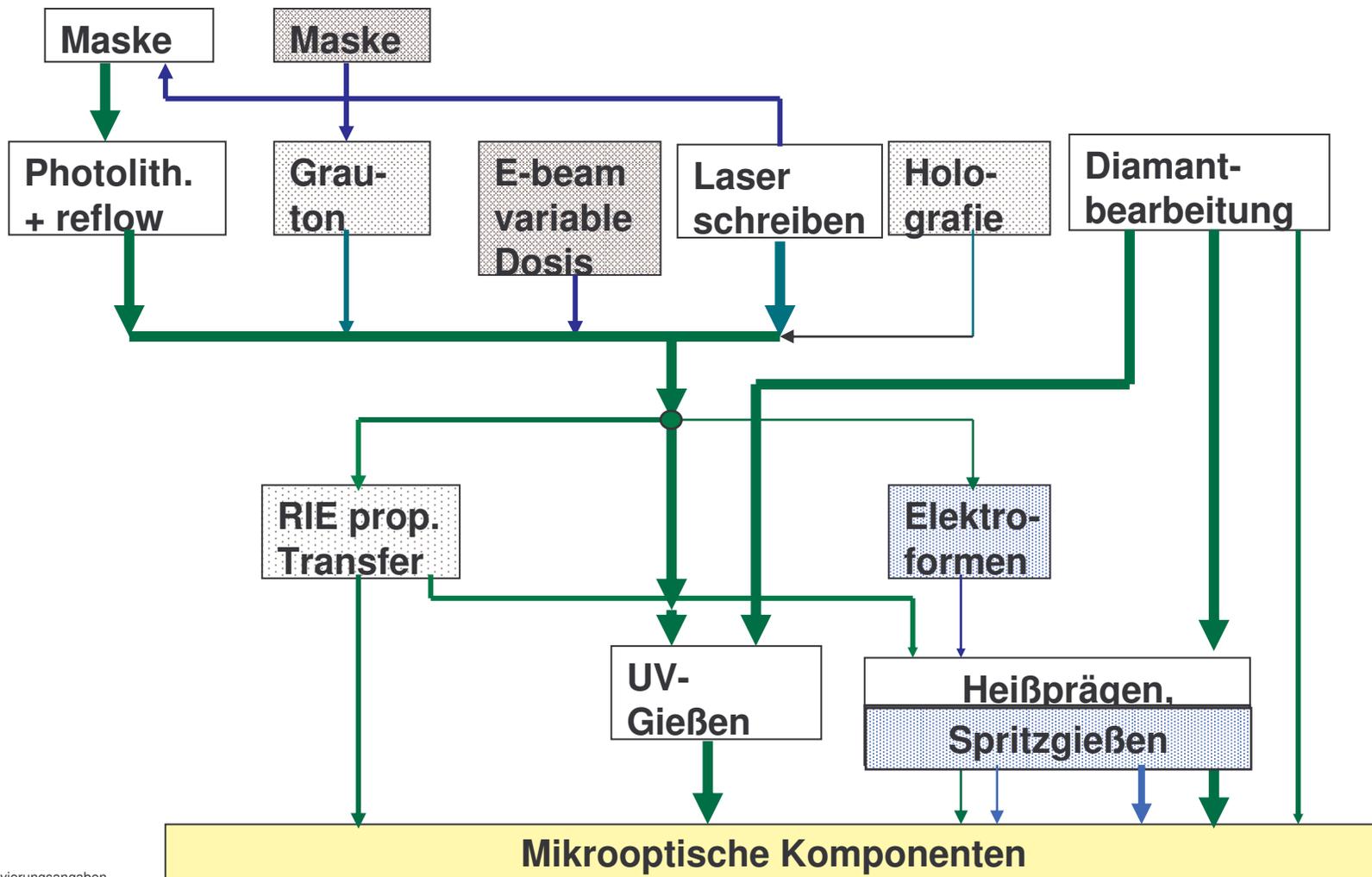
Archivierungsangaben

Fig. 4. Top-view images of surface-structured OSRAM chips. Various chip sizes have been fabricated with similar luminous efficiencies, demonstrating the scalability of the concept.

Seite 41

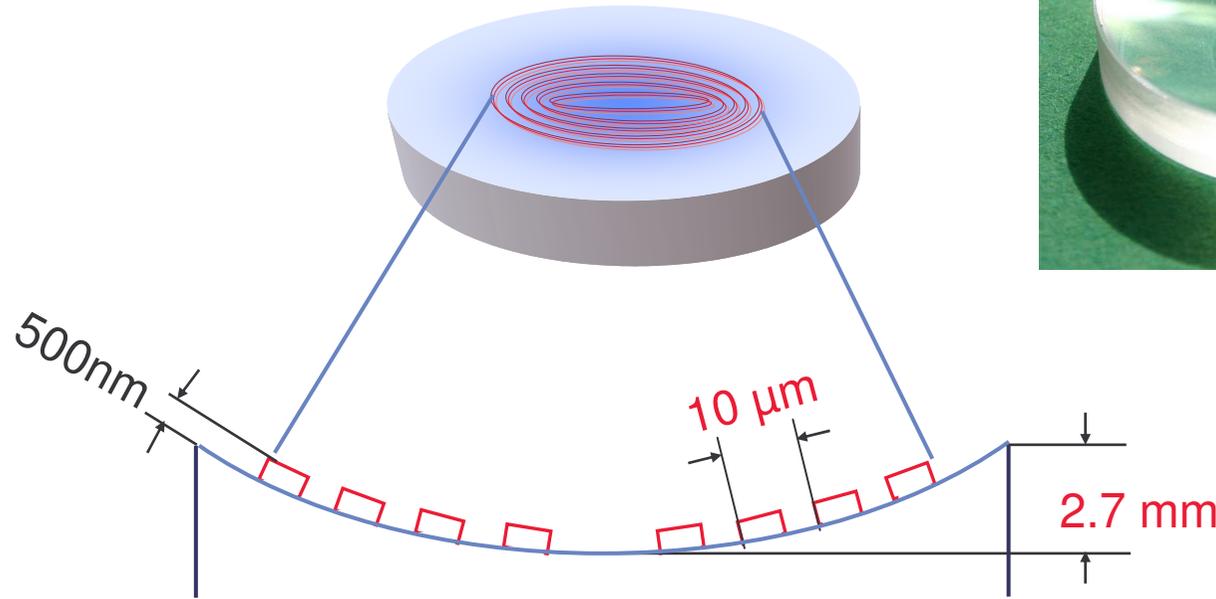


Fraunhofer Institut
Angewandte Optik
und Feinmechanik



Diffraktive Strukturen auf gekrümmten Flächen

radial symmetrisch



$\Lambda = 3\mu\text{m}$ – z.Z. kleinste Periode

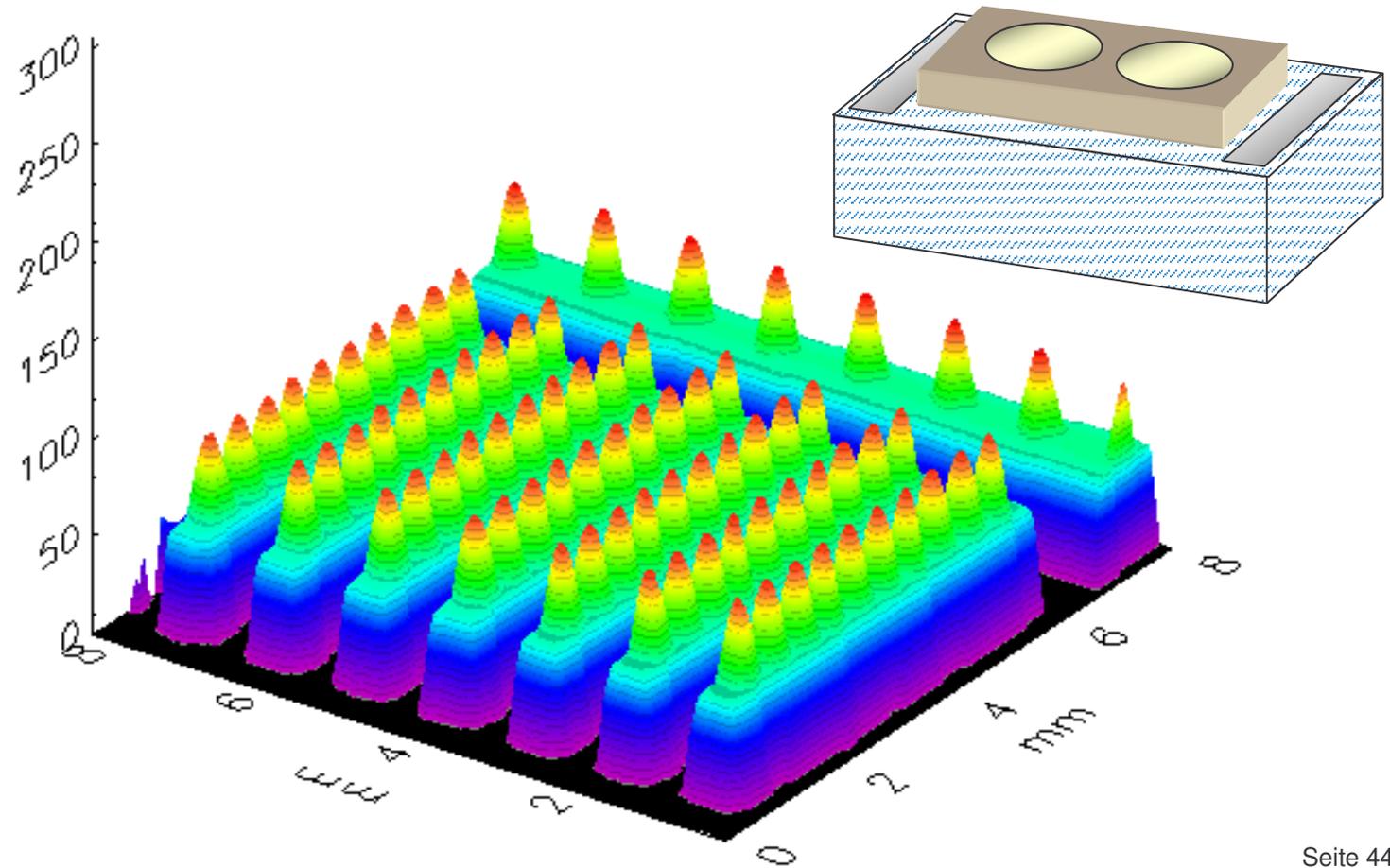
Geplante Anwendung: Near-to-eye display

IOF: Laserschreiber (NT), auch SPDT



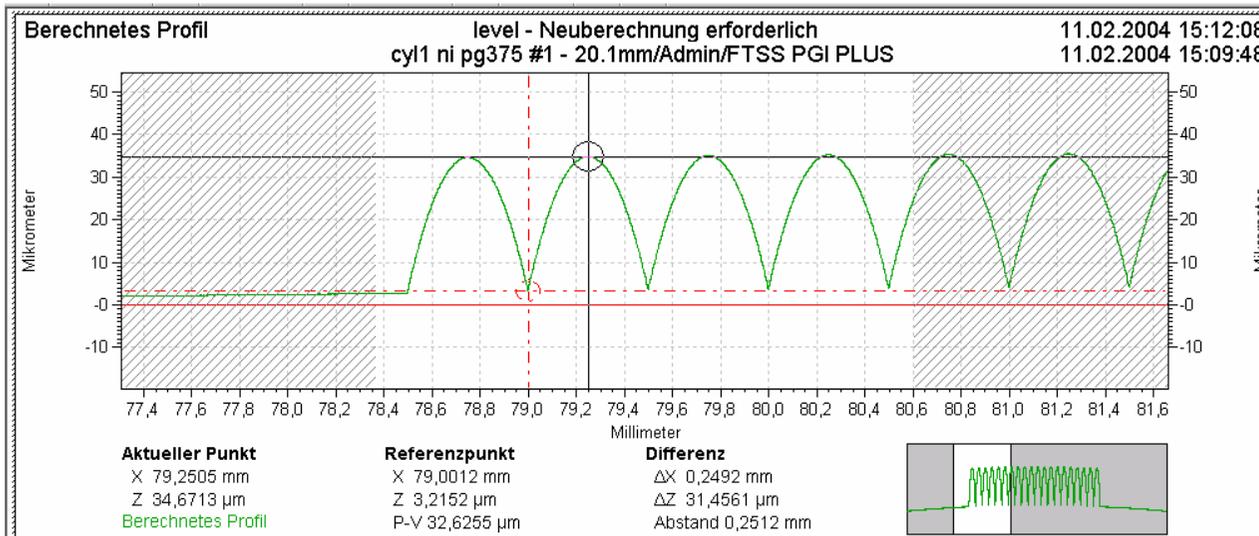
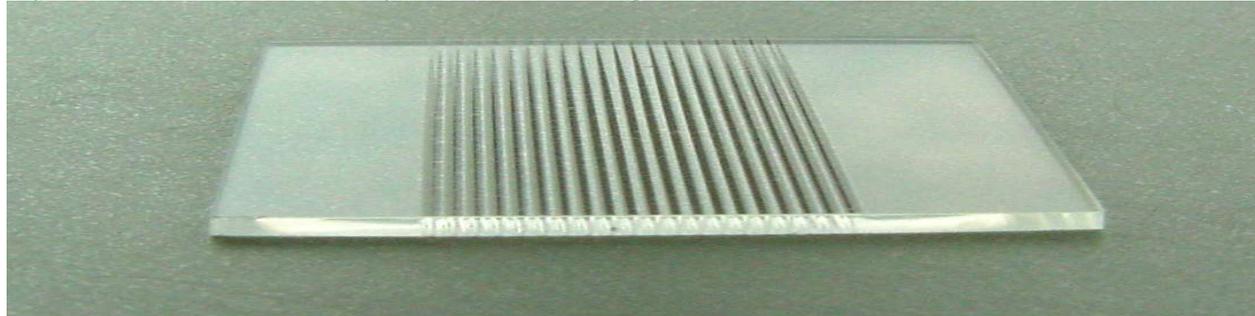
Linsenarray

Präpariert für Trennen
mittels Wafersäge



Glaspressen mit Nanometer-Präzision

Zylinderlinsenarray (Werkzeug: Ni)



Danksagung:

A.Bräuer

P.Dannberg

J. Duparre

E.B.Kley

P.Schreiber

U.Zeitner

