Applications of Multilayer optics

Zhanshan Wang, Jingtao Zhu, Baozhong Mu, Zhong Zhang, Fengli Wang, Jing Xu, Lingyan Chen

Institute of Precision Optical Engineering (IPOE)
Physics Department, Tongji University, Shanghai 200092, China
Outline

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  - Design
  - Fabrication
    - Characterization
  - Applications of multilayer optics
- Summary and outlook
Motivations

X-ray lasers

Astronomical observation

inertial confinement fusion

Synchrotron Radiation

Non-periodic multilayer coatings: special requirements
Design of multilayer optics

Keys of design

Merit functions
- Different applications need different merit functions

Optimized algorithms
- 1 simulated annealing algorithm
- 2 Random search method
- 3 Local optimized algorithms

Starting structures
- 1 Quarter wave periodic multilayers
- 2 Multilayer stacks with a variety of periods
- 3 Initial solutions made by analytical expression
Fabrication of multilayer optics

Magnetron Sputtering systems
Characterization of multilayer optics

D1 X-ray diffractometer made by Bede Company

XE—100 atomic force microscope

Soft X-ray polarimeter in BESSY II
Applications of multilayer optics

1. X-ray KB microscopes

KB microscope is one of essential diagnostic tools in ICF research.

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Applications of multilayer optics

1. X-ray KB microscopes

Difficulties in making KB microscope

- High quality mirrors
  a) Mirror fabrication
  b) Coating
- Assembly and alignment
  a) How to assemble the mirrors?
  b) How to adjust the assembly in diagnostics experiments?
Applications of multilayer optics

1. X-ray KB microscopes

Mirrors: Ir single layer, W/B4C periodic multilayers, non-periodic multilayers

X-ray energy: 8keV
Applications of multilayer optics

1. X-ray KB microscopes

Comparison of three kind of microscopes

X-ray energy: 8keV
Magnification: 10×

<table>
<thead>
<tr>
<th>Performance</th>
<th>Single layer</th>
<th>W/B₄C periodical multilayer</th>
<th>W/B₄C non-periodical multilayer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial resolution (µm)</td>
<td>6</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Field of view (µm)</td>
<td>±100</td>
<td>±100</td>
<td>±200</td>
</tr>
<tr>
<td>Spectral resolution (E/ΔE)</td>
<td>none</td>
<td>40</td>
<td>10</td>
</tr>
</tbody>
</table>
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1. X-ray KB microscopes

Advanced KB microscope:
Better resolution, large field of view
Applications of multilayer optics

1. X-ray KB microscopes

Imaging experiment at 4.75keV on Laser Facility

CH target was fixed on the reference plane, the best object position.

• Diagram of 1D-AKB diagnostics
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- X-ray imaging experiments is necessary
- The determination of best grazing incidence angle and best object point is complicated.

We proposed a multilayer method to play the alignment of soft x-ray KB microscope in air.
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Periodic multilayer ML2

Periodic multilayer ML1

B₄C/W

Substrate

4.75keV

8keV
Applications of multilayer optics

Calculated reflectivity of various number of periodic layers working at 4.75keV

Calculated reflectivity of various number of periodic layers working at 8keV
Applications of multilayer optics
Applications of multilayer optics

Reflectivity vs. Grazing Angle

- 4.75 keV, N=4
- 8 keV, N=10

θ = 0.134
θ = 0.303
• Imaging experiments at 8keV energy

Object is 600lp/inch Au mesh.

Intensity distribution

Resolution

measured resolution (μm)

object field (μm)

80%
Imaging results at 4.75keV on Laser Facility

1500lp/inch Au mesh

pixel (1 pixel = 24 μm × 14.56 ×)
Applications of multilayer optics

- 2D-KB microscope working at 4.75keV

Experimental schematic of 2D-KB microscope in Laser Facilities
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- **2D-KB microscope working at 4.75keV**

  Ti target
  X-Rays
  Laser Beam
  \(100\text{ps}, 800\text{J}\)

  \(2\text{ns}, 300\text{J} \times 8\)
  Laser Beam

  Cylindrical target

  Change the time difference

  \(1\text{mm} \times \Phi 260\mu\text{m}\)

  \(20\mu\text{m}\)
Application in 2.5keV KB microscopes

Periodic multilayer ML2 N=5
Periodic multilayer ML1 N=40

Substrate

Cr/C
B₄C/W

[Cr/C]₅-[B₄C/W]₄₀ ML

Reflectivity

Grazing Angle / deg

8keV imaging results

2.5keV imaging results

100um

8keV HR=51.91%
2.5keV HR=60.83%
(1.52-1.80)deg>20%
HR at 1.63deg
Roughness=0A

HR at 1.63 deg
Roughness=0A

8keV imaging results
Applications of multilayer optics

2 HR@30.4nm for He-II, AR@58.4nm for He-I

A EUV telescope on the moon

30.4nm imaging of magnetosphere

58.4nm light from ionsphere
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2 HR@30.4nm for He-II, AR@58.4nm for He-I
Applications of multilayer optics

3 Multilayer Collimator at 19.5nm

Parabolic Mirror

Secondary Mirror

Primary Mirror

Source

CCD

R

wavelength (nm)

ΔD/D

X position (mm)

±0.27%
Summary and outlook

The multilayer coatings have been designed and successfully fabricated.

The experimental results agree with the design ones and show good property.

Improving the performance of multilayers and new multilayer applications
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