



中科院长春光机所
CIOMP

A Novel Model for Coated System Analysis in Extreme Ultra-Violet Lithography

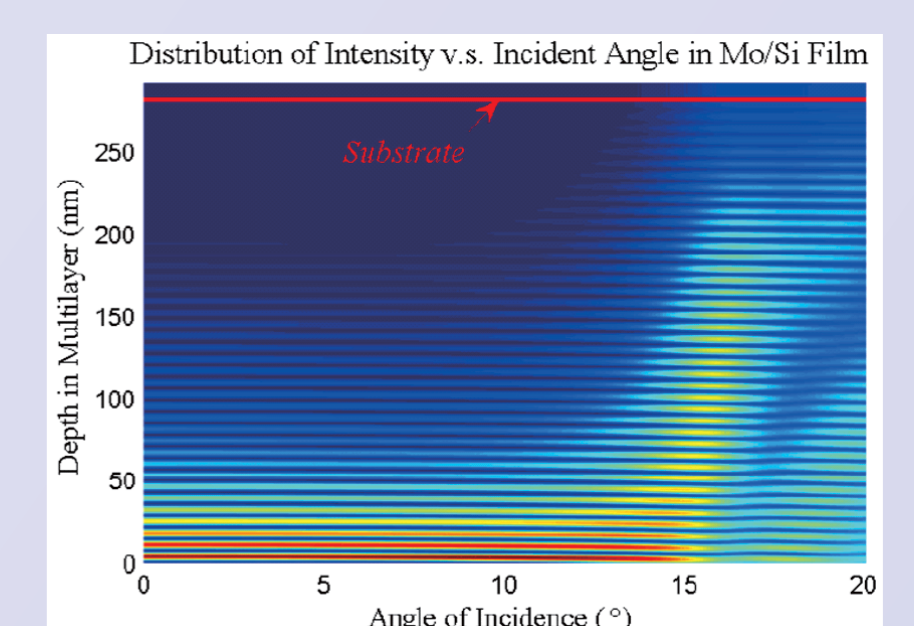
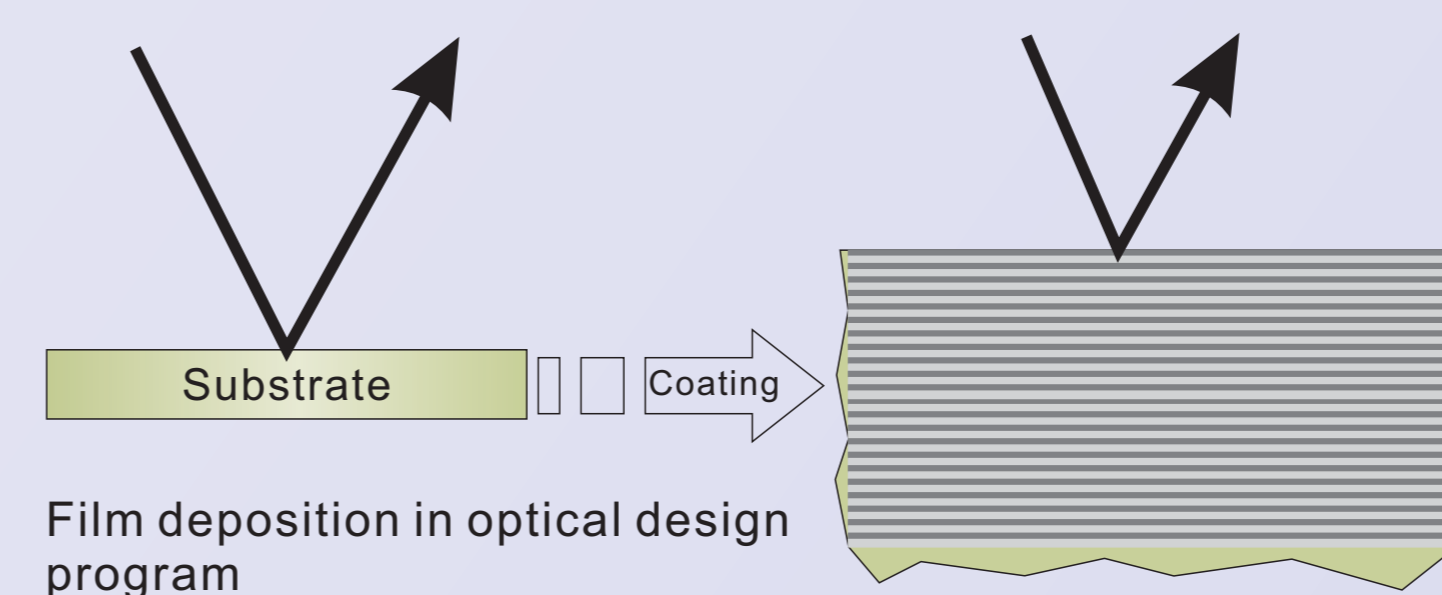
Changchun Institute of Optics, Fine Mechanics and Physics,
Chinese Academy of Sciences, Changchun, Jilin, 130033
Wang Jun*, Jin Chun-shui, Wang Li-ping, Xie Yao

Outline

- Introduction
- EWSE based on Energy Conservation
 - ↳ Theoretical Deduction
 - ↳ Equivalent System
 - ↳ Experiments
- Summary

Introduction

- ✦ WaveFront Error for EUVL: $\lambda/14 \sim 1$ nm RMS
- ✦ Multilayer Coatings: 40~60 bilayers, Thickness@~300 nm
- ✦ Commercial Optical Design Software
 - Single work surface
 - Coating=energy apodization+phase shift
- ✦ FDTD



Equivalent Work Surface

- ↳ Physics optics ↔ Geometrical Optics
- ↳ Multilayer films ↔ Figure of Mirrors

Ref.: [1] J. Wesner, F. Eisenkramer, J. Heil et al.. Improved polarization ray tracing of thin-film optical coatings[J]. 2004, 5560 261-272
[2] M. F. Bal, M. Singh, J. J. M. Braat. Optimization of multilayer reflectors for extreme ultraviolet lithography[J]. Journal of Microlithography, Micro-fabrication, and Microsystems, 2004, 3 (4): 537

Equivalent Work Surface model based on Energy Conservation

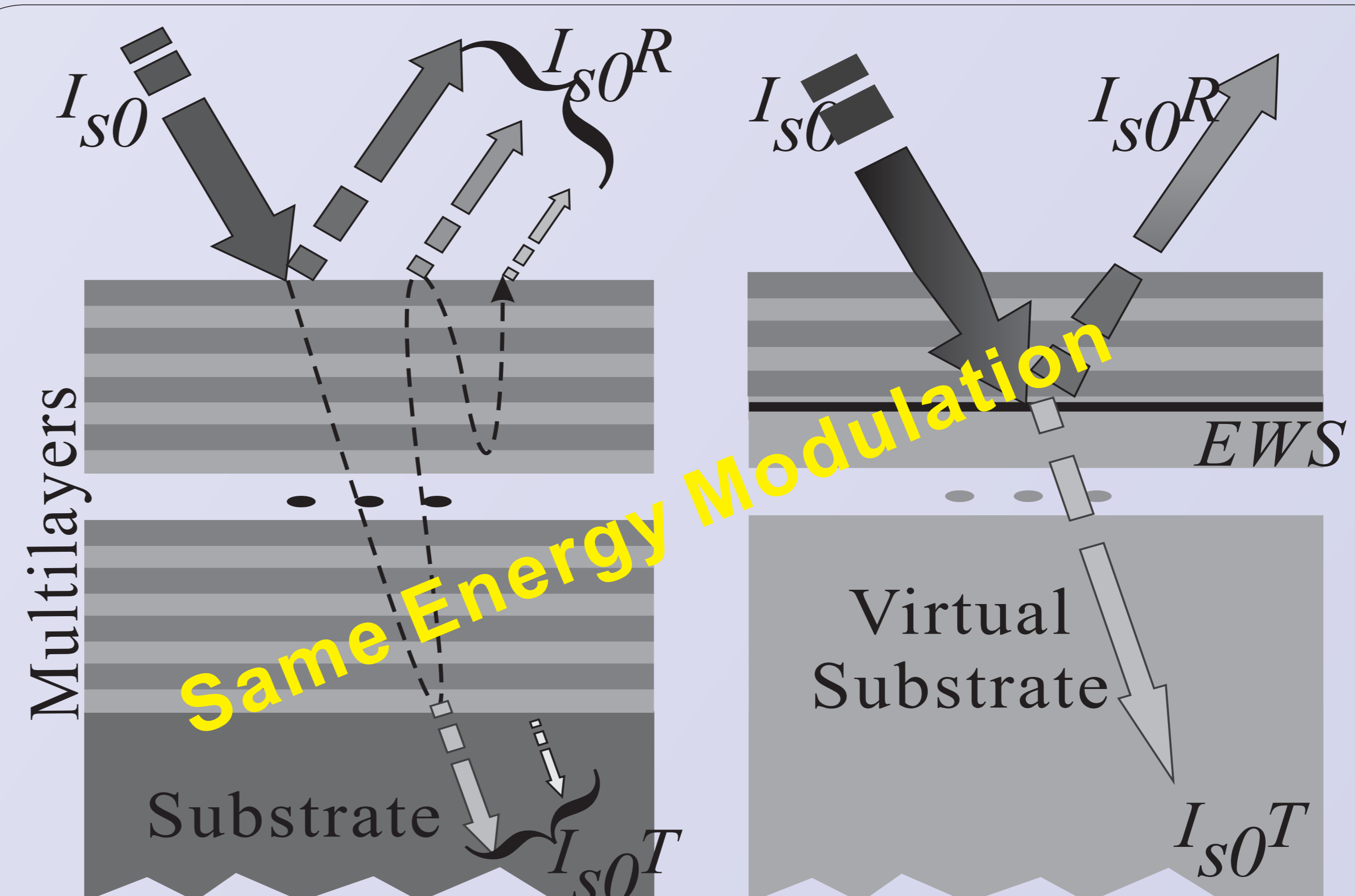
- Multilayer Films:
- ↳ Energy Modulation
 - ◎ Aberrations

When a beam emerges from vacuum to medium:

$$\begin{aligned} \vec{E}(z, \theta_0) &= \varepsilon \exp \left[i\omega t - \left(\frac{2\pi N(z)}{\lambda} \right) r(z, \theta_0) \right] \\ &= \varepsilon \exp \left[- \left(\frac{2\pi k(z)}{\lambda} \right) r(z, \theta_0) \right] \\ &\quad * \exp \left[i\omega t - \left(\frac{2\pi n(z)}{\lambda} \right) r(z, \theta_0) \right] \end{aligned} \quad (1)$$

and define an attenuation factor:

$$C_{att} = I_s(z)/I_{s0} = \exp \left[- \frac{4\pi}{\lambda} \int_0^{D'} k(z) dz \right] \quad (2) \quad \text{find } D'$$



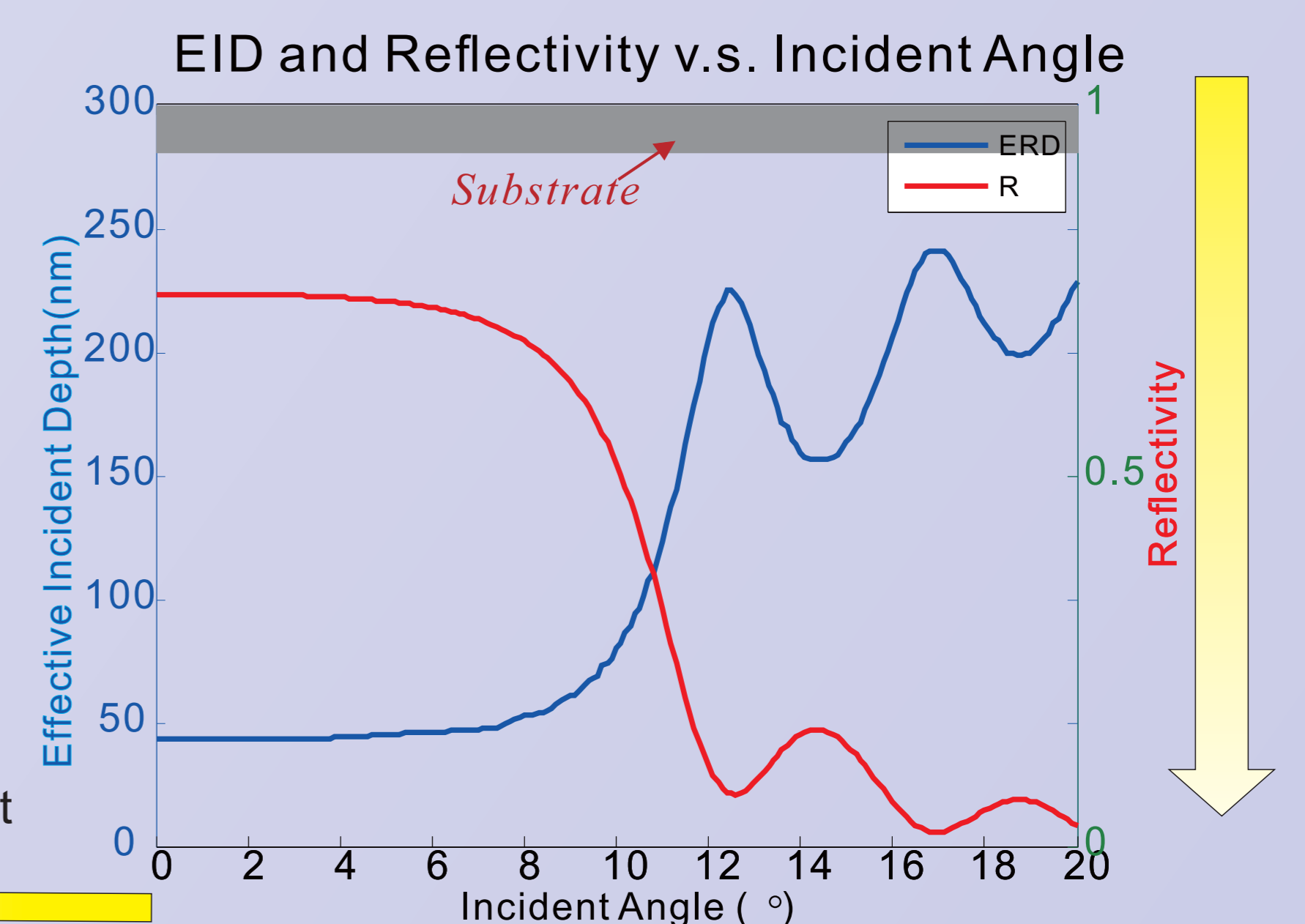
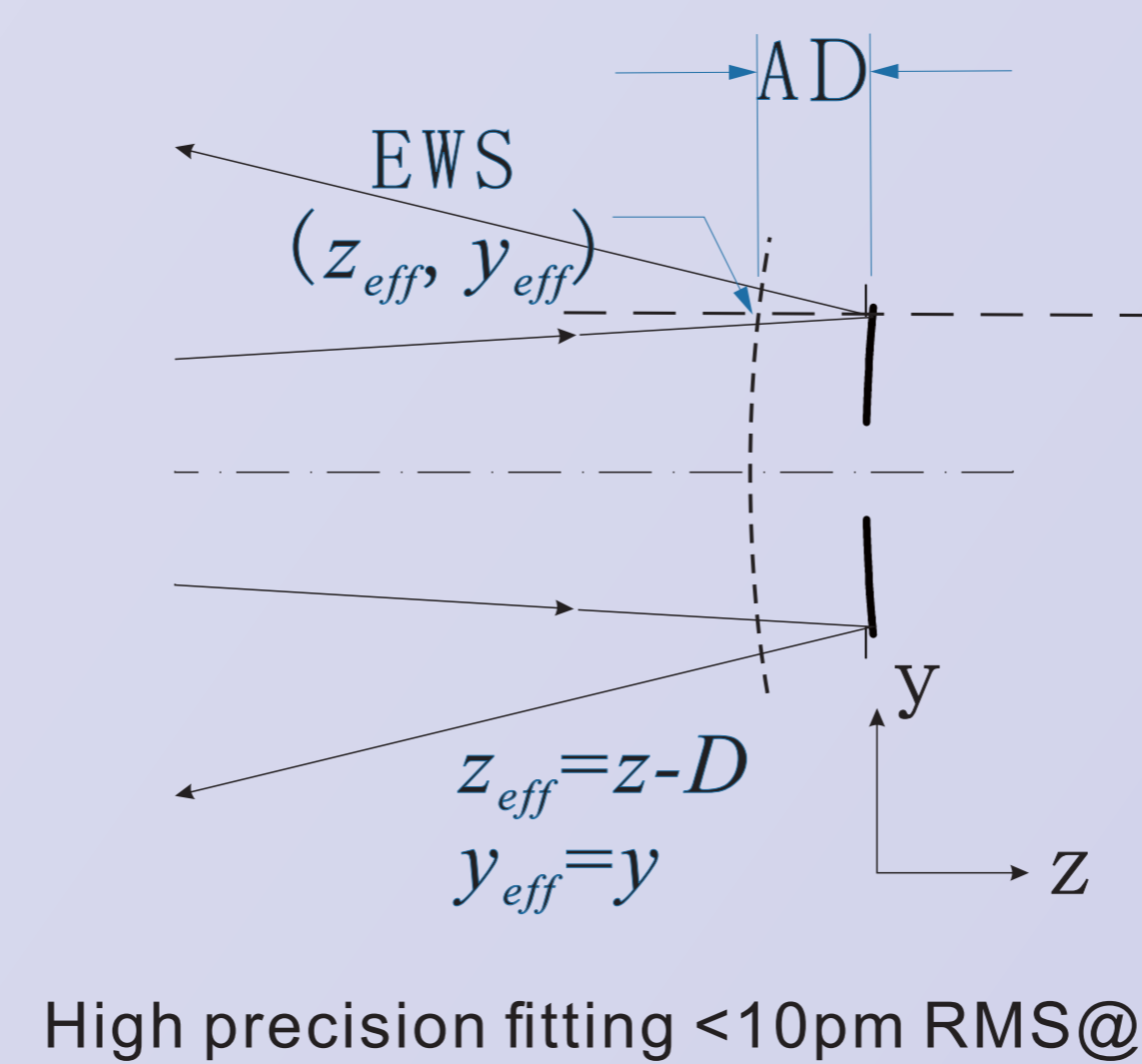
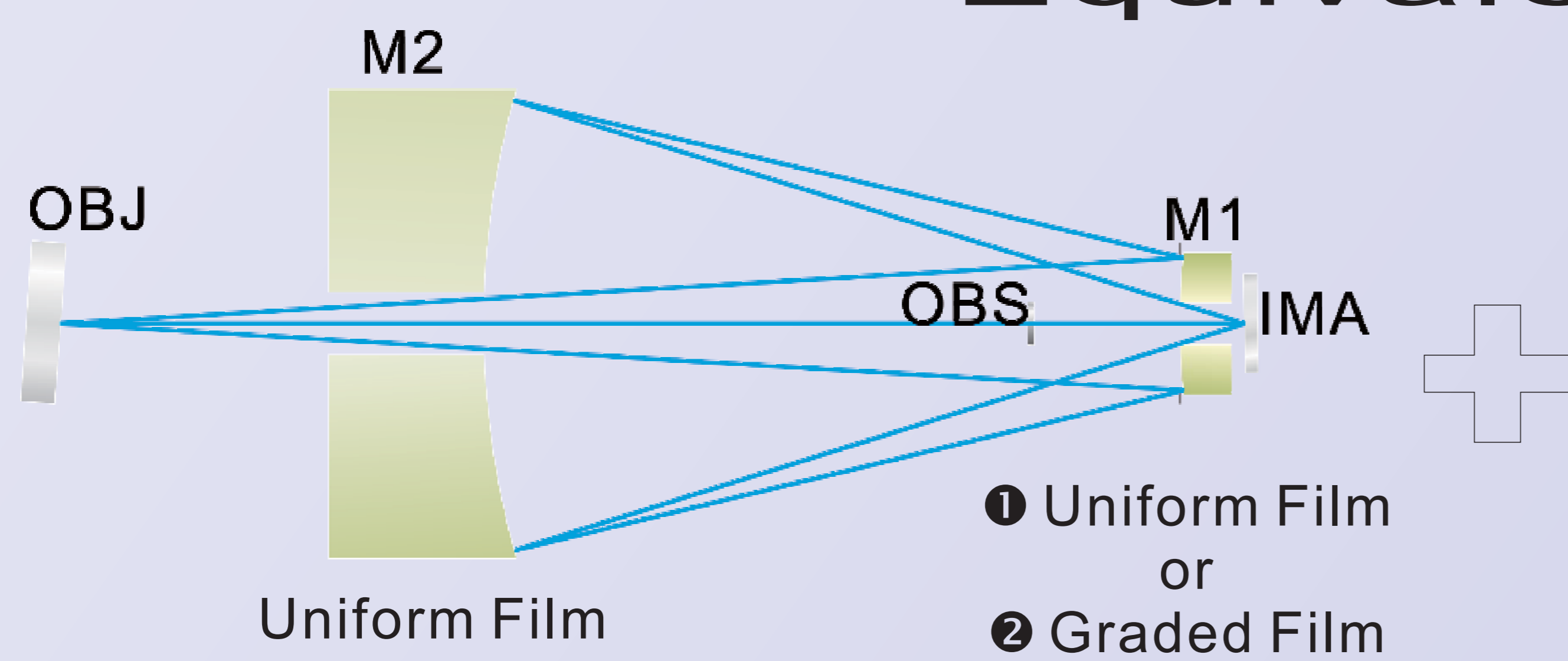
$$[I_{s0} (\delta S \cos \theta_i) C_{att} - I_{st} (\delta S \cos \theta_t)] C_{att} = I_{sr} (\delta S \cos \theta_r) \quad (3)$$

$$C_{att} = \frac{T + \sqrt{T^2 + 4R}}{2}$$

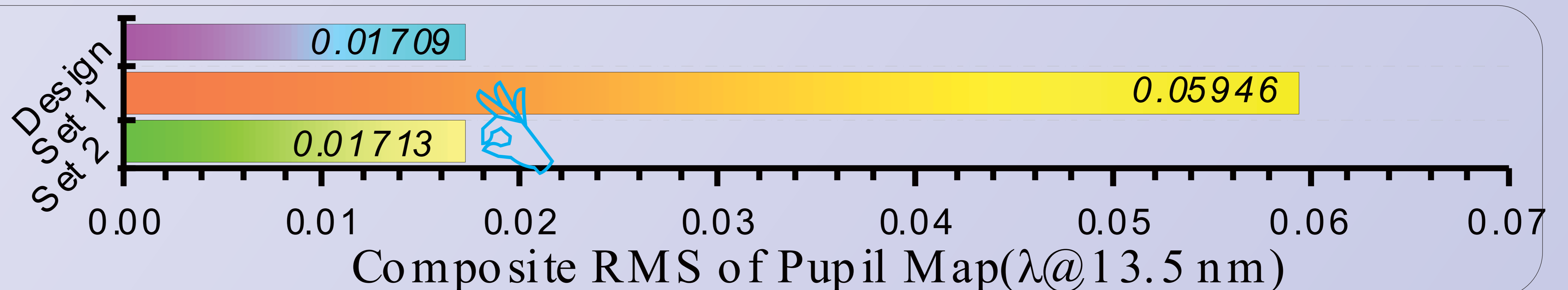
Framework for the EWSE model

$$D' \xrightarrow{\text{Multiple reflections and transmissions in } D'} D'' = D' \exp(-R') \xrightarrow{\text{Surface reflection back into vacuum in advance}} D = (1 - R_0) D' \exp(-R') \quad \text{EWSE Updating}$$

Equivalent System



Results



Summary

- ✓ Developed a novel model EWSE for multilayer film coated EUVL system based on the energy conservation principle intuitive, widely adapted, the same energy modulation to real coated element
- ✓ Equivalent system can be constructed from EWSE and high precision fitting method sharing with optical design program, easy to do, a two mirror projection was illustrated
- ✓ With the aid of ICA (instantaneous clear aperture), EWSE can be used for large field, higher NA projections