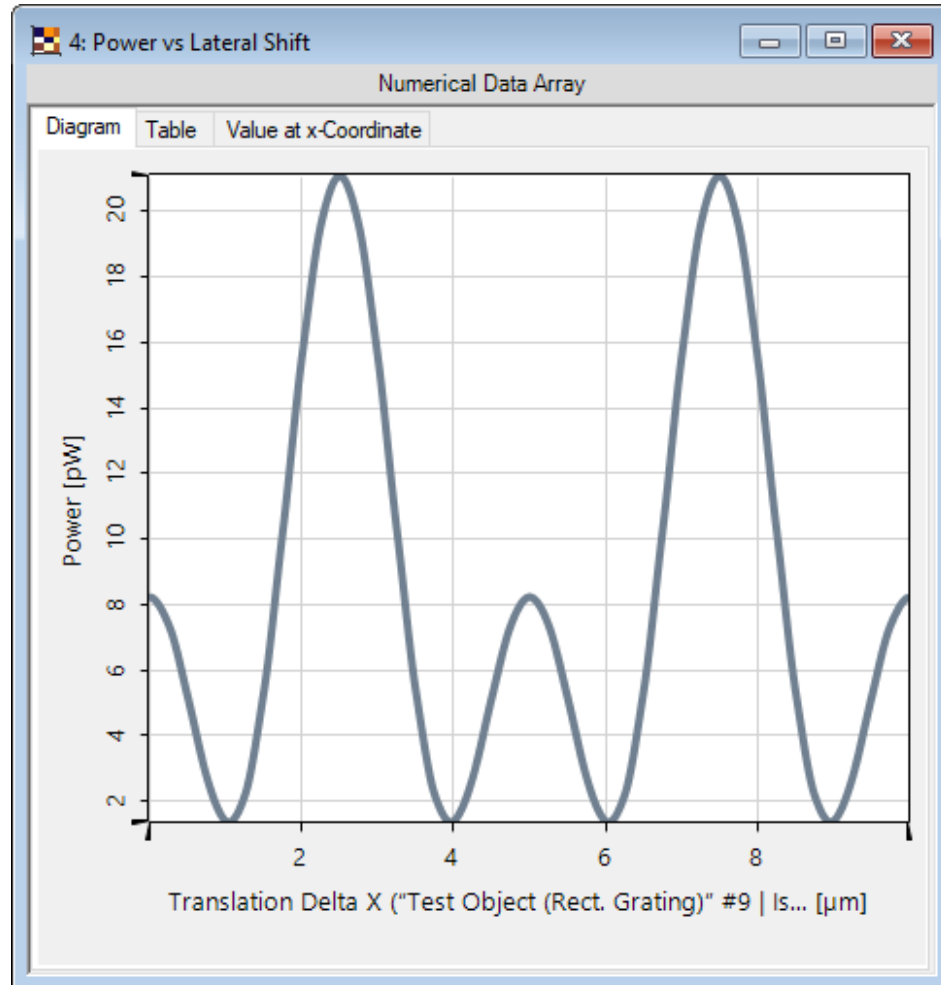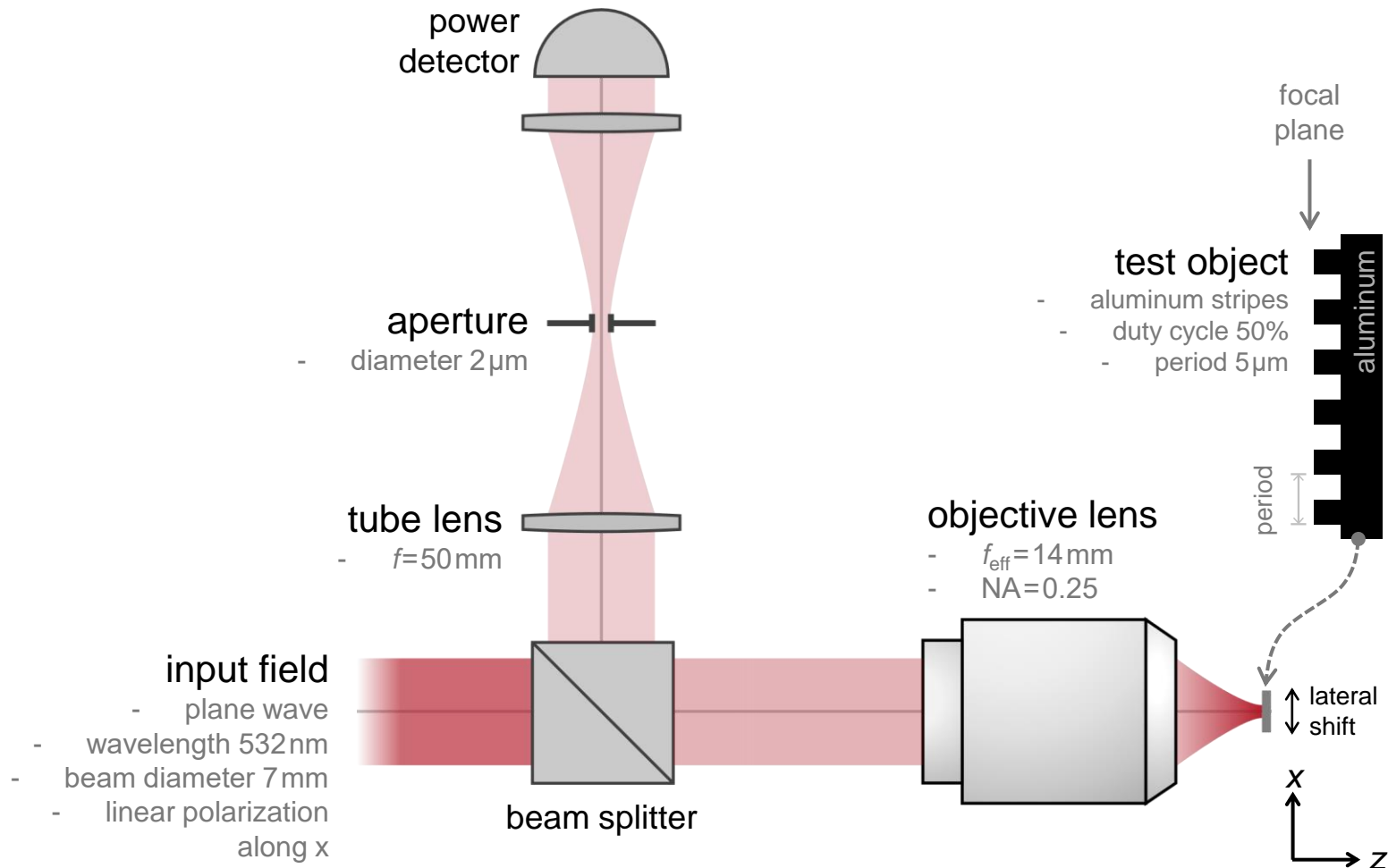# Working Principle of Confocal Scanning Microscopes
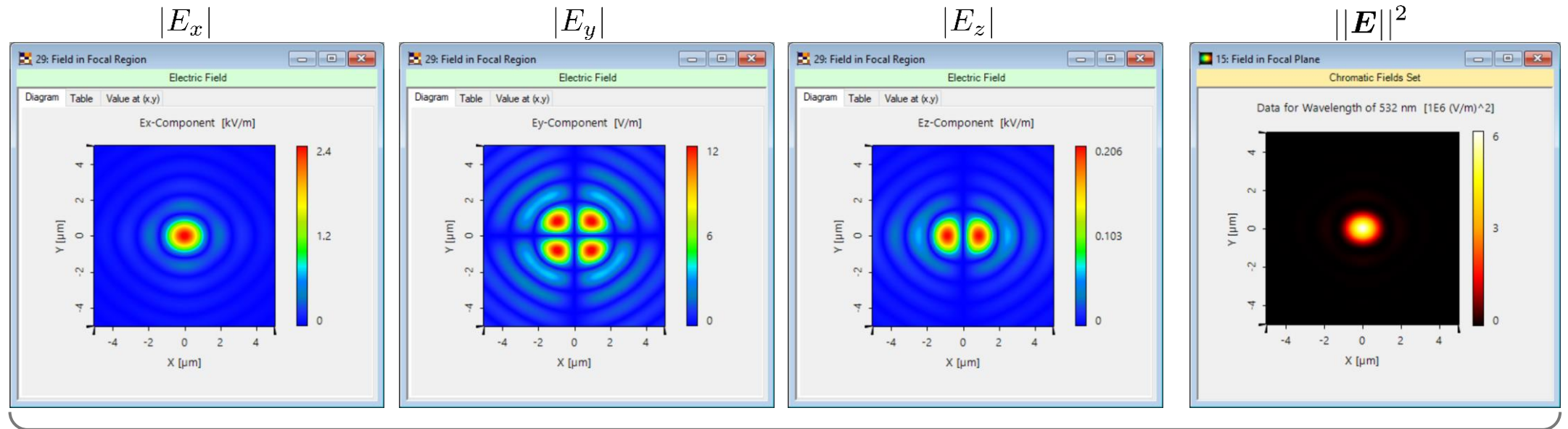
Abstract

Confocal scanning microscopy, after its invention and patent by M. L. Minsky in the 1950s and later with the novelty of employing lasers as the source, has lent itself to widespread use. By using a spatial pinhole to block the light scattered or reflected from out-of-focus planes, it helps improve the longitudinal resolution and contrast. In this example, we build a confocal scanning microscope in VirtualLab Fusion, and use a metallic grating with alternating ridges and grooves as the test object to demonstrate its working principle.
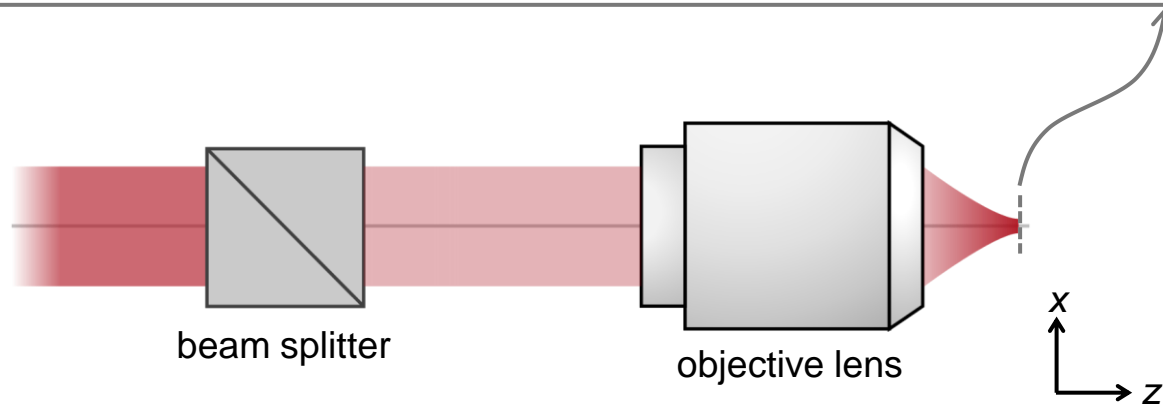
Modeling Task

power
detector

focal
plane

test object
- aluminum stripes
- duty cycle 50%
- period 5 μm

aperture
- diameter 2 μm

aluminum

period

tube lens
- $f = 50\,\text{mm}$

objective lens
- $f_{\text{eff}} = 14\,\text{mm}$
- $\text{NA} = 0.25$

input field
- plane wave
- wavelength 532 nm
- beam diameter 7 mm
- linear polarization along x

beam splitter

lateral shift

x

z

How does a confocal scanning microscope work, and how is it used to detect power changes with respect to the lateral shift of the object?
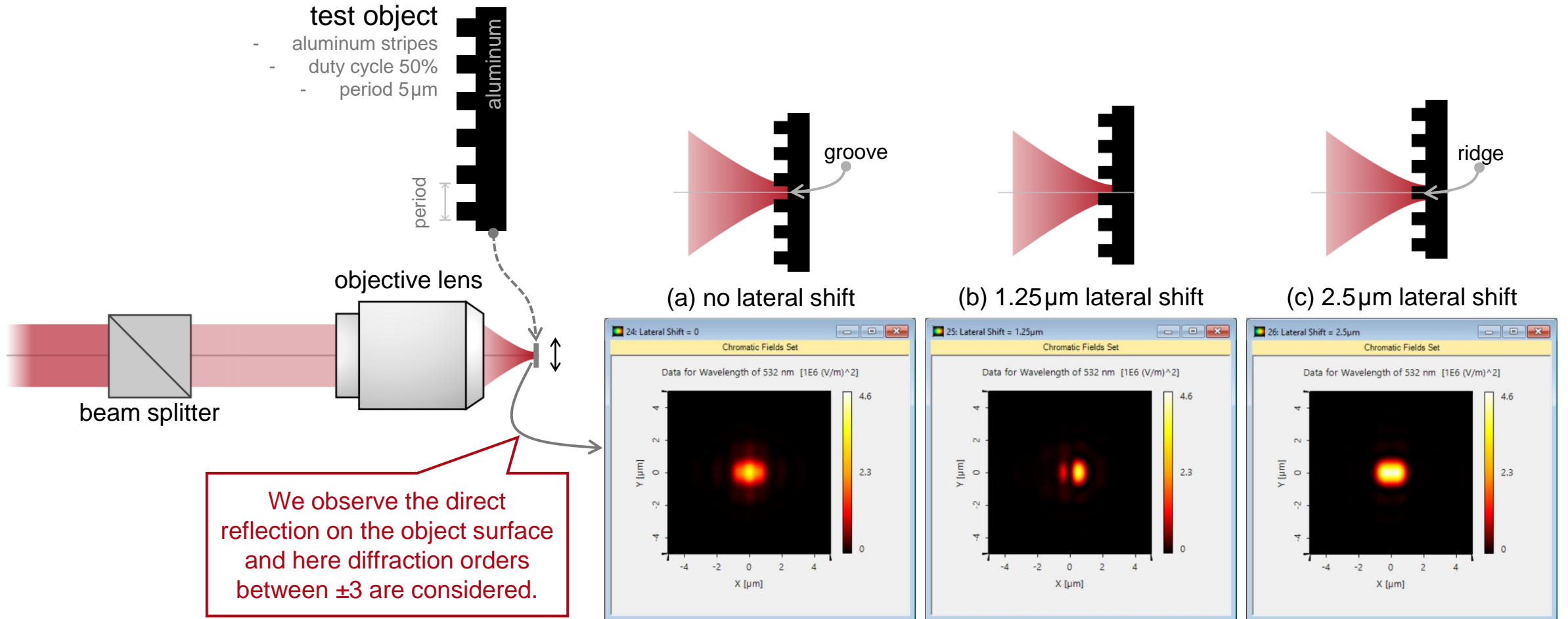
Probe Field in Focal Region

$$|E_x|$$

$$|E_y|$$

$$|E_z|$$

$$||\boldsymbol{E}||^2$$

input field
- plane wave
- wavelength 532 nm
- beam diameter 7 mm
- linear polarization

beam splitter

objective lens

Direct Reflection from the Test Object

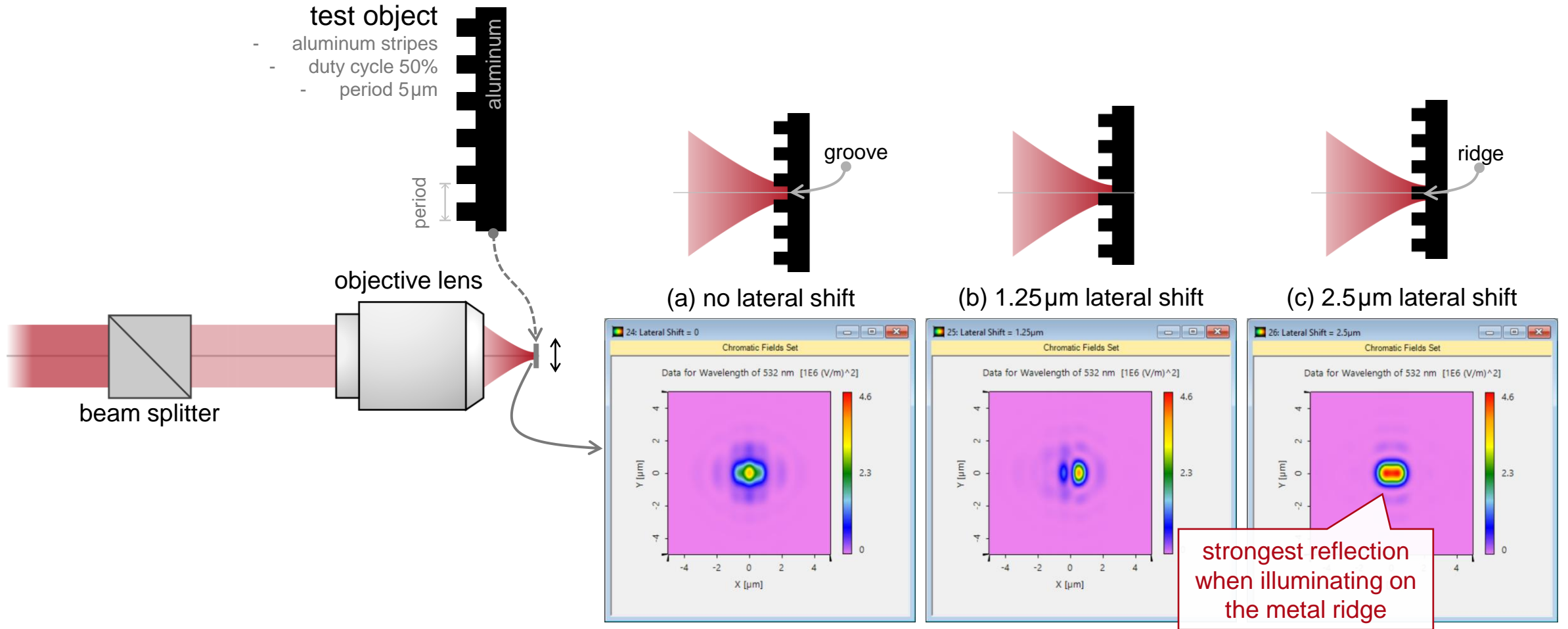test object
- aluminum stripes
- duty cycle 50%
- period 5µm

aluminum

period

objective lens

beam splitter

We observe the direct reflection on the object surface and here diffraction orders between ±3 are considered.

groove

(a) no lateral shift

ridge

(b) 1.25µm lateral shift

(c) 2.5µm lateral shift

24: Lateral Shift = 0
Chromatic Fields Set
Data for Wavelength of 532 nm [1E6 (V/m)^2]

25: Lateral Shift = 1.25µm
Chromatic Fields Set
Data for Wavelength of 532 nm [1E6 (V/m)^2]

26: Lateral Shift = 2.5µm
Chromatic Fields Set
Data for Wavelength of 532 nm [1E6 (V/m)^2]

Direct Reflection from the Test Object

test object
- aluminum stripes
- duty cycle 50%
- period 5 μm

aluminum

period

objective lens

beam splitter

groove

ridge

(a) no lateral shift

(b) 1.25 μm lateral shift

(c) 2.5 μm lateral shift
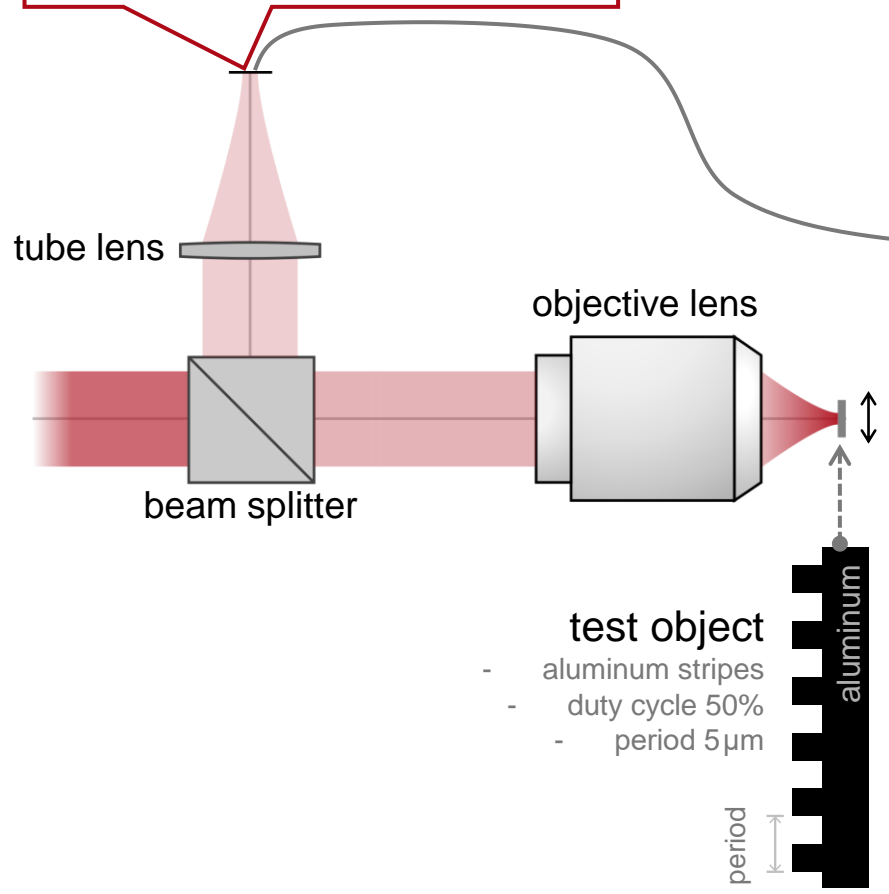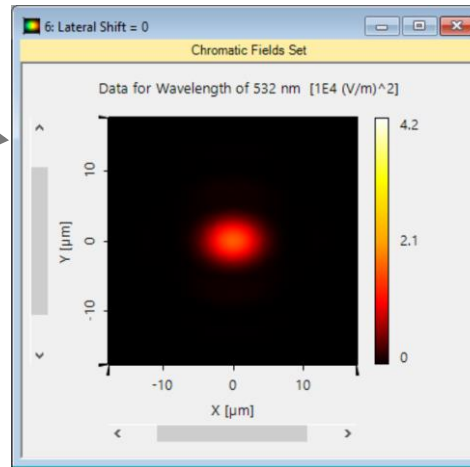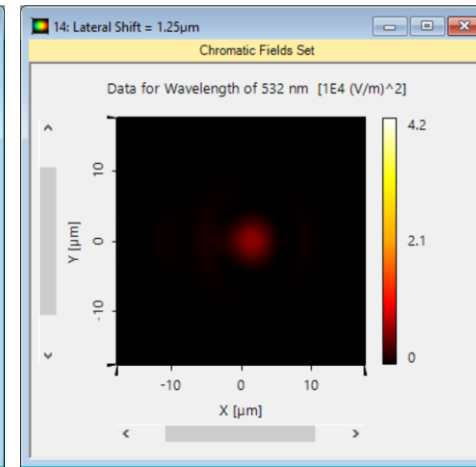
strongest reflection when illuminating on the metal ridge

Image of Test Object

We observe the image behind the tube lens and only the diffraction orders within ±3 contribute to the imaging.
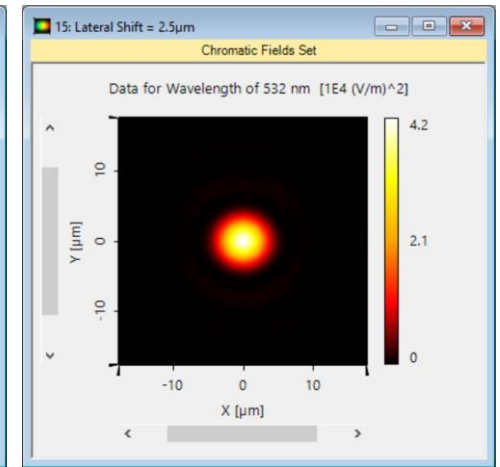
tube lens

objective lens

beam splitter

test object
- aluminum stripes
- duty cycle 50%
- period 5 μm

aluminum

period

(a) no lateral shift

6: Lateral Shift = 0
Chromatic Fields Set
Data for Wavelength of 532 nm [1E4 (V/m)^2]

(b) 1.25 μm lateral shift

14: Lateral Shift = 1.25μm
Chromatic Fields Set
Data for Wavelength of 532 nm [1E4 (V/m)^2]

(c) 2.5 μm lateral shift

15: Lateral Shift = 2.5μm
Chromatic Fields Set
Data for Wavelength of 532 nm [1E4 (V/m)^2]

(a) no lateral shift

(b) 1.25 µm lateral shift

(c) 2.5 µm lateral shift

tube lens

objective lens

beam splitter

test object
- aluminum stripes
- duty cycle 50%
- period 5 µm

aluminum

period
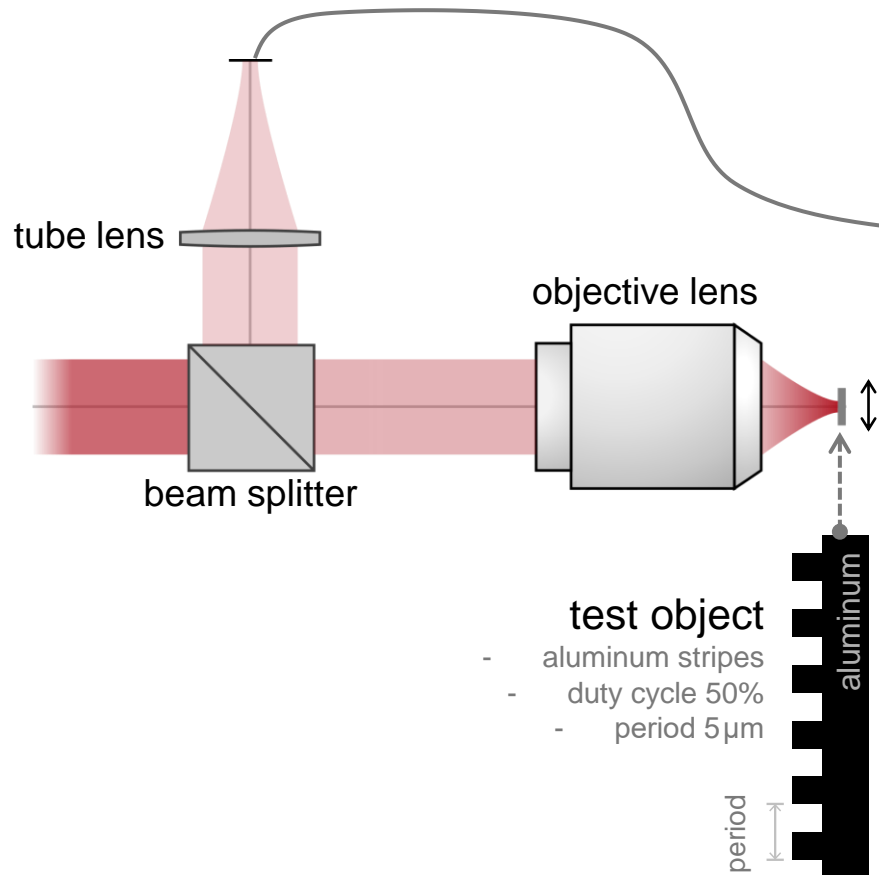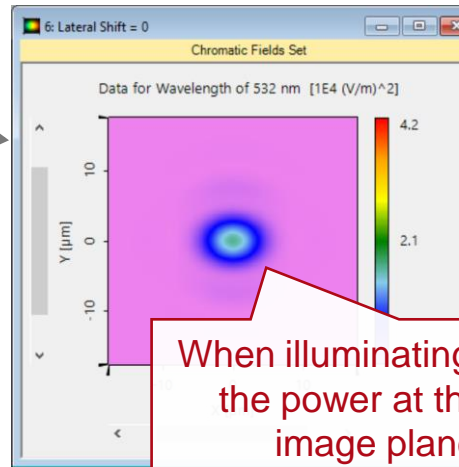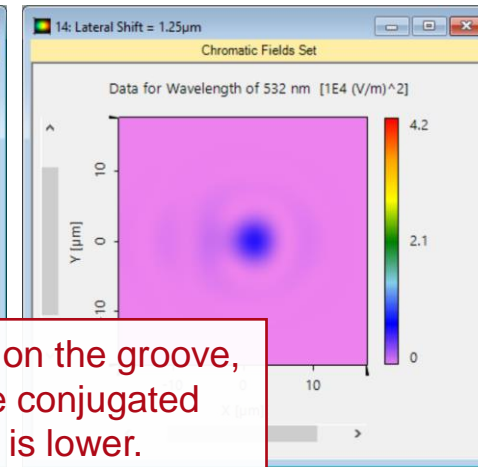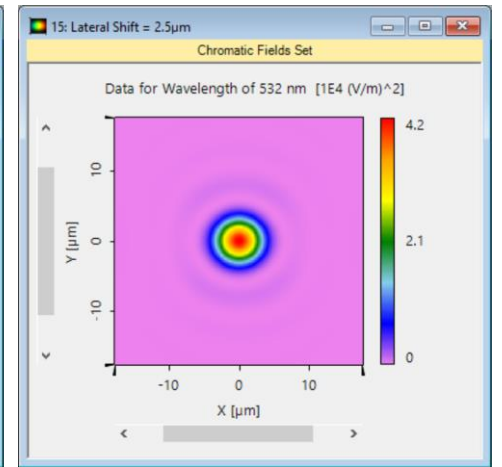
When illuminating on the groove, the power at the conjugated image plane is lower.

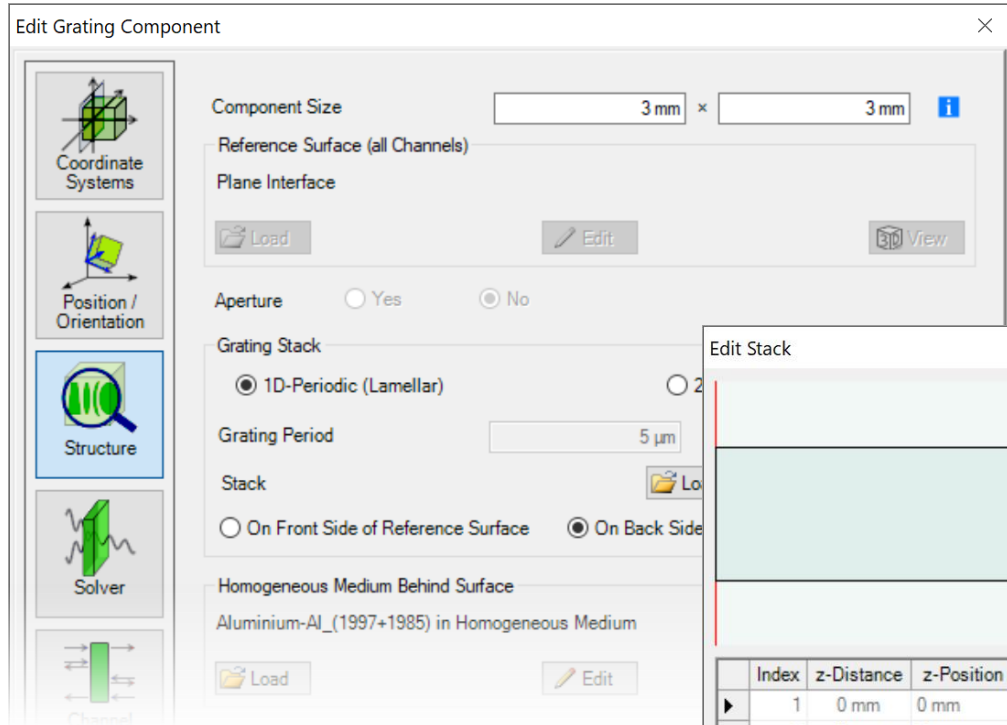Reflection from the groove is out of focus!

focal plane
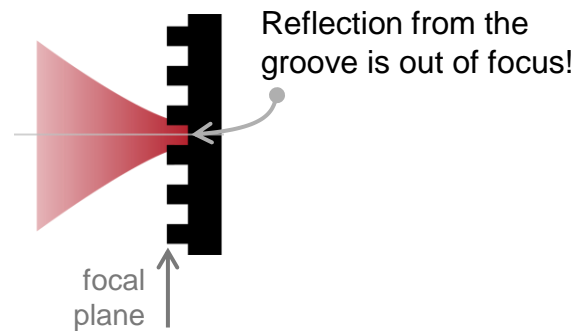
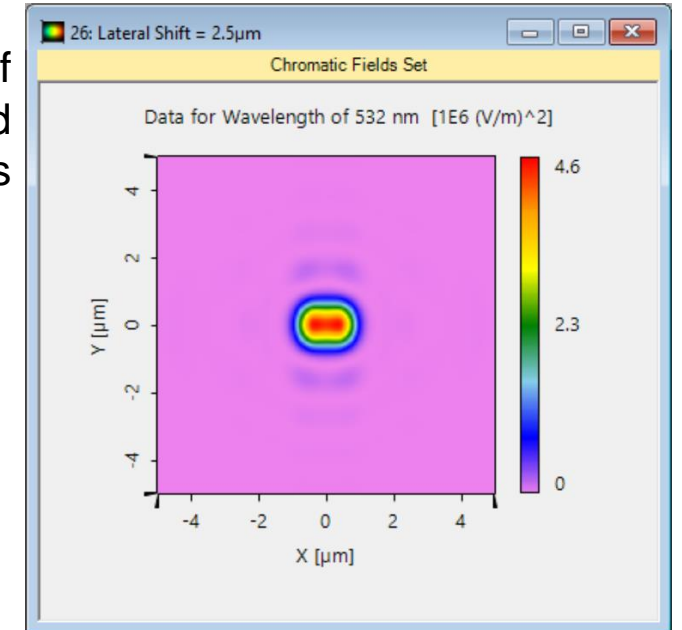# Power Measurement vs Lateral Shift of Test Object
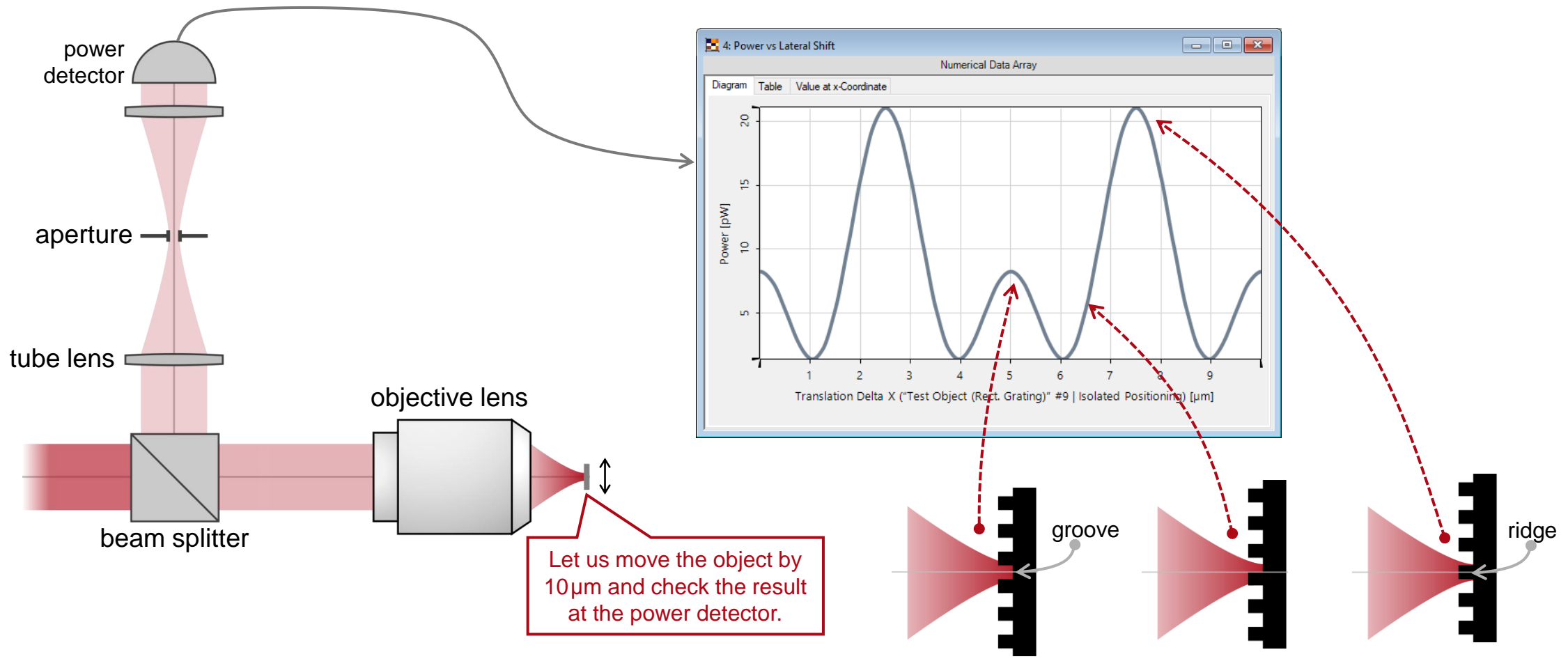
Peek into VirtualLab Fusion

inclusion and configuration of gratings within system

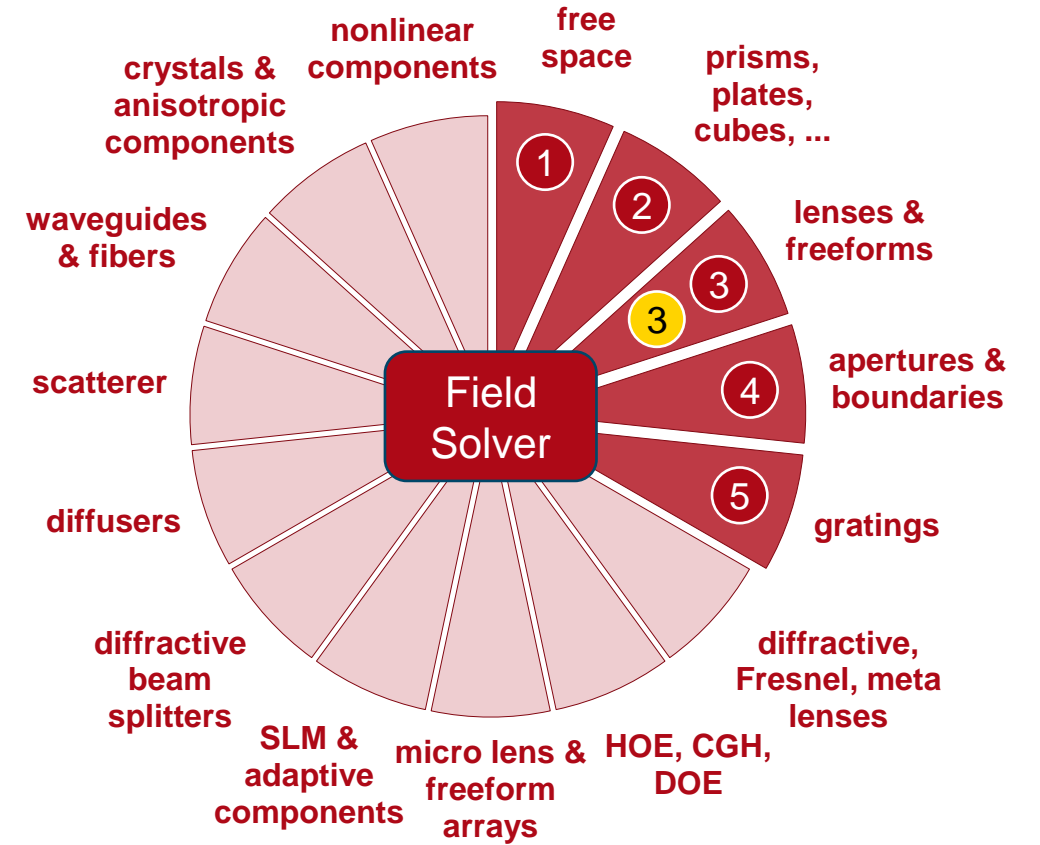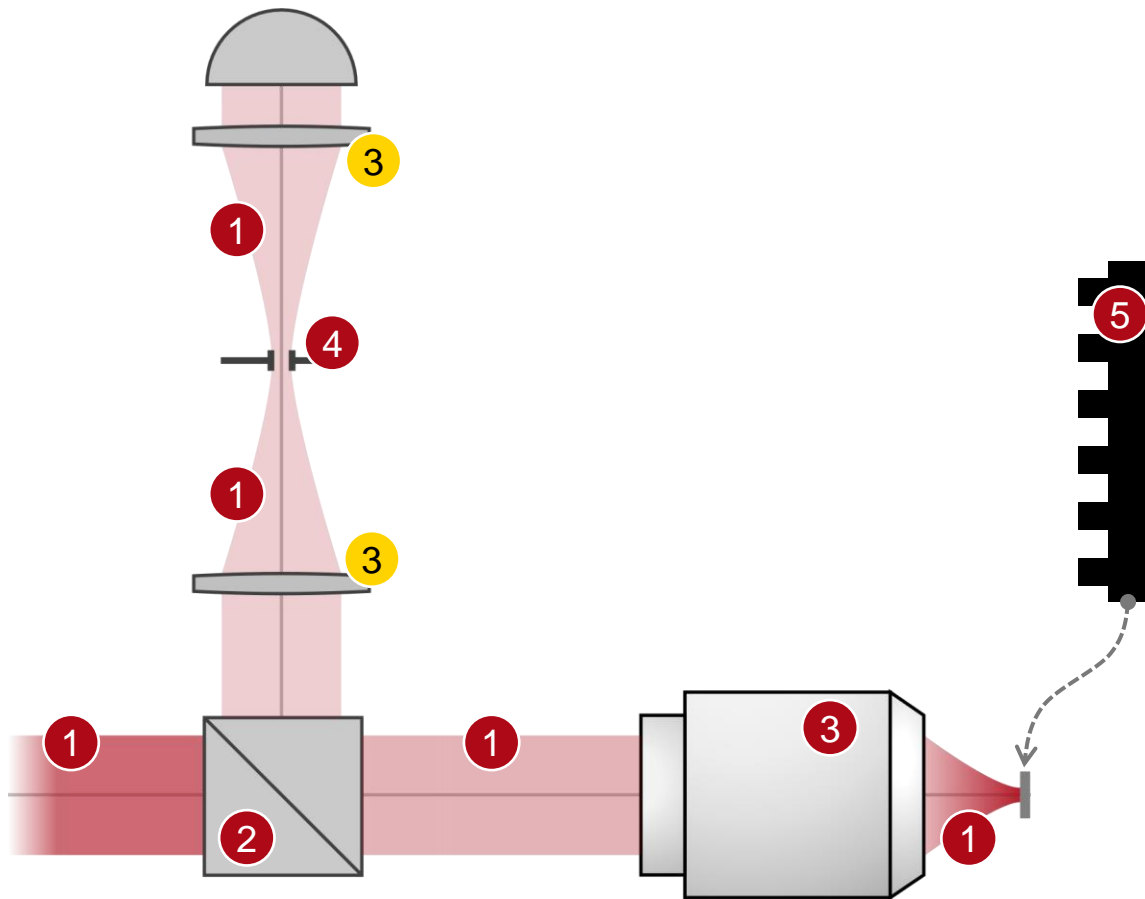analysis/visualization of electromagnetic field interaction with gratings

Workflow in VirtualLab Fusion

- Construct grating structures using interfaces
  - [Configuration of Grating Structures by Using Interfaces](#) [Use Case]

- Grating modeling within complex system
  - [Modeling of Gratings within Optical System – Discussion at Examples](#) [Use Case]

- Set channels properly for multi-pass simulation
  - [Channel Configuration for Surfaces and Grating Regions](#) [Use Case]

- Use Parameter Run to check influence/changes
  - [Usage of the Parameter Run Document](#) [Use Case]
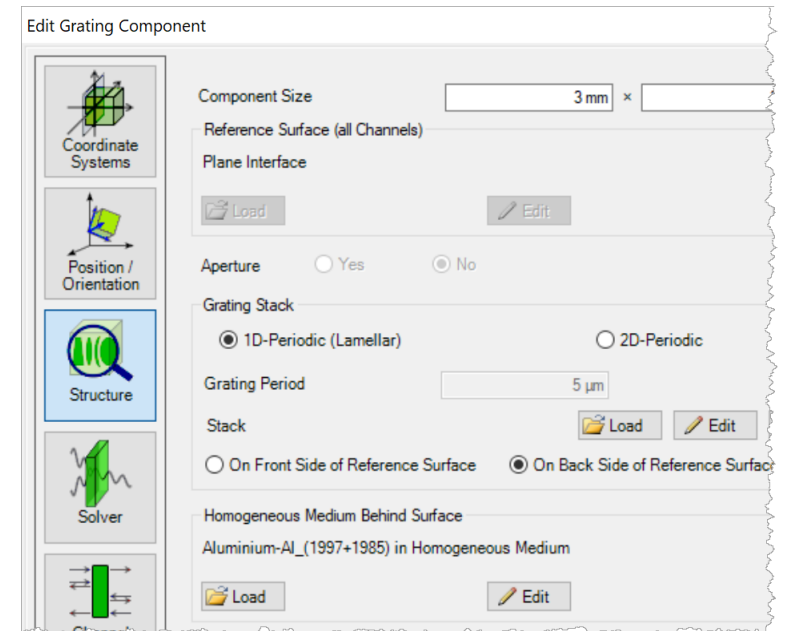
VirtualLab Fusion Technologies

idealized component

Document Information

title	Working Principle of Confocal Scanning Microscopes
document code	MIC.0010
version	1.2
edition	VirtualLab Fusion Advanced
software version	2020.1 (Build 3.4)
category	Application Use Case
further reading	- Demonstration of Abbe's Theory of Image Formation - Modeling of Gratings within Optical System - Discussion at Examples