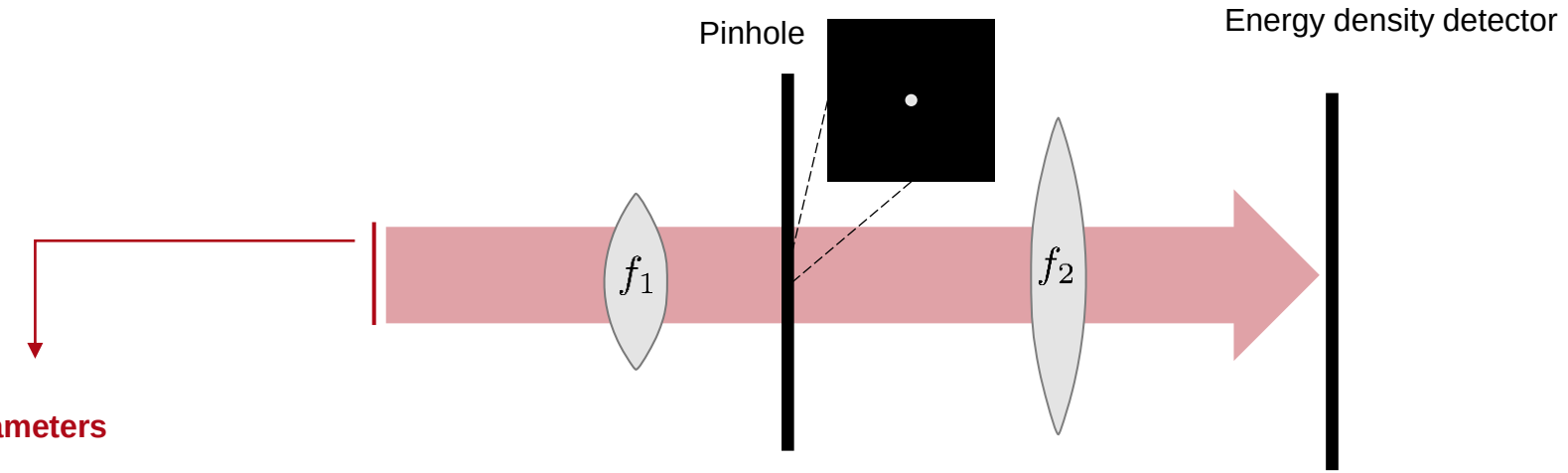
Circularly Serrated Aperture for Beam Apodization

Abstract

There is a growing demand for laser beams with uniform energy distribution (flat-top beams) in various industry sectors. It is known that beams with steep edge profiles are more prone to develop diffraction ripples. These ripples may intensify in certain optical systems e.g., amplifiers through self-focusing. In this use case, we seek to tackle this challenge by introducing a serrated beam apodizer. Beam apodization plays a key role in the design of high-energy lasers and beam delivery systems. Using amplitude-only apertures in high-energy optical systems leads to higher durability compared to apertures fabricated with deposition techniques.

Schematic Illustration of Setups

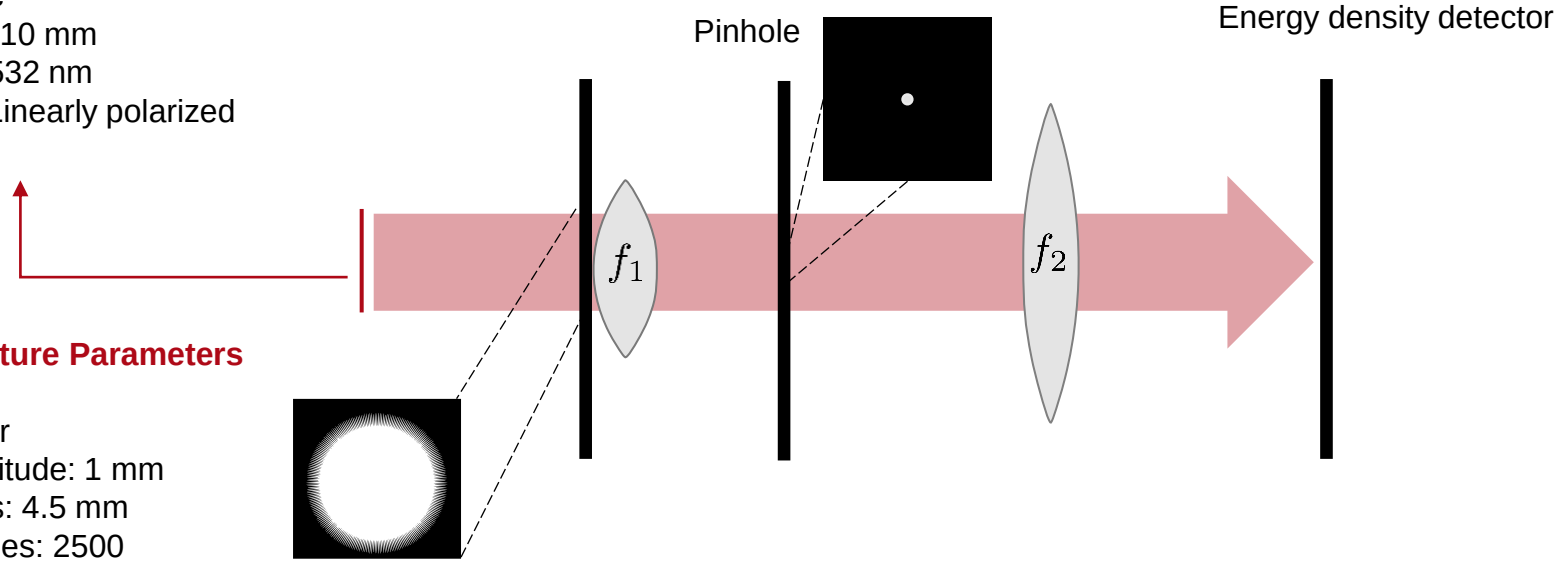
a) Reference Setup



Source Parameters

Truncated plane wave
Shape: Elliptic
Diameter: 10x10 mm
Wavelength: 532 nm
Polarization: Linearly polarized

b) Setup with beam apodizer

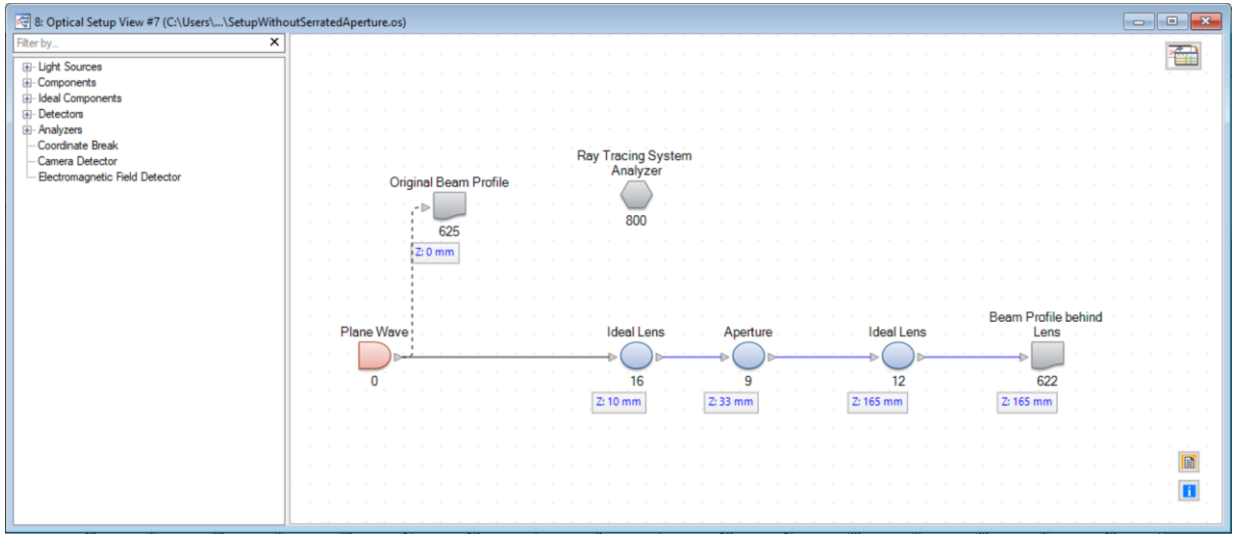


Serrated Aperture Parameters

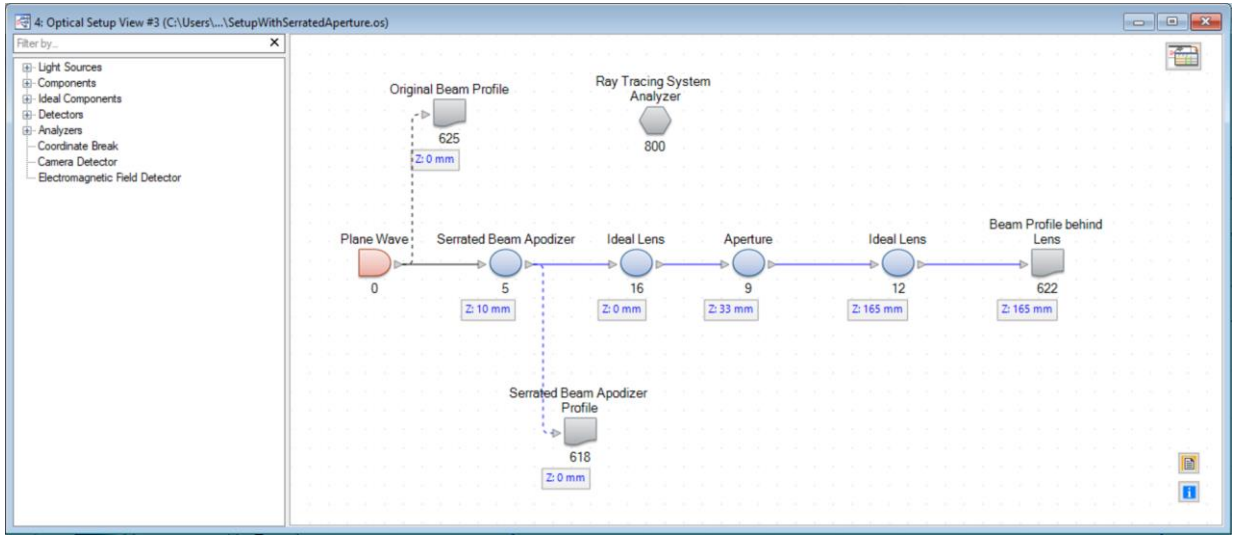
Shape: Circular
Serrating amplitude: 1 mm
Average radius: 4.5 mm
Number of ridges: 2500

Setups Overview in VirtualLab Fusion

a) Reference Setup



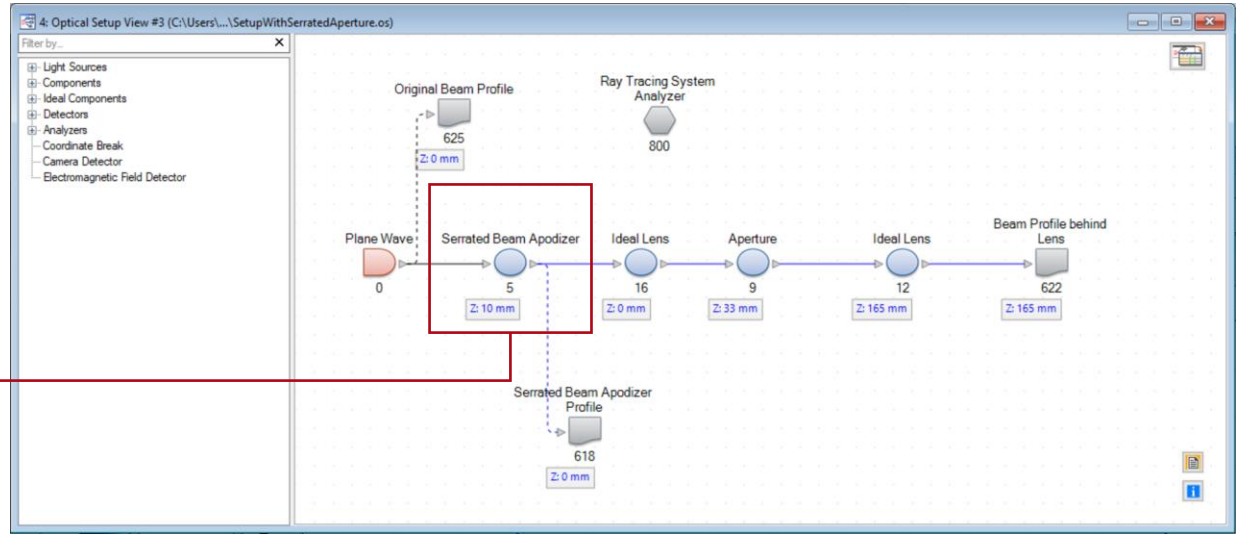
b) Setup with beam apodizer



Programming Serrated Aperture Using Programmable Function

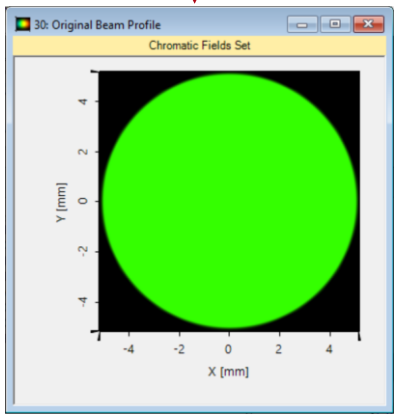
Programmable Function

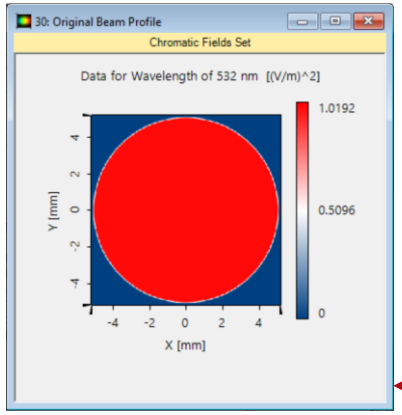
```
double realPart = 0.0;
double imaginaryPart = 0.0;
double serrationCoefficient = AverageRadius * (1 + (SerratingAmplitude / AverageRadius));
double serratedRadius = serrationCoefficient * Math.Sin(0.5 * Period * Math.Atan2(y, x)) * Math.Sin(0.5 * Period * Math.Atan2(y, x));

if (serratedRadius >= Math.Sqrt((Math.Pow(x, 2) + Math.Pow(y, 2)))) {
    realPart = 1.0;
}

return new Complex(realPart, imaginaryPart);
```

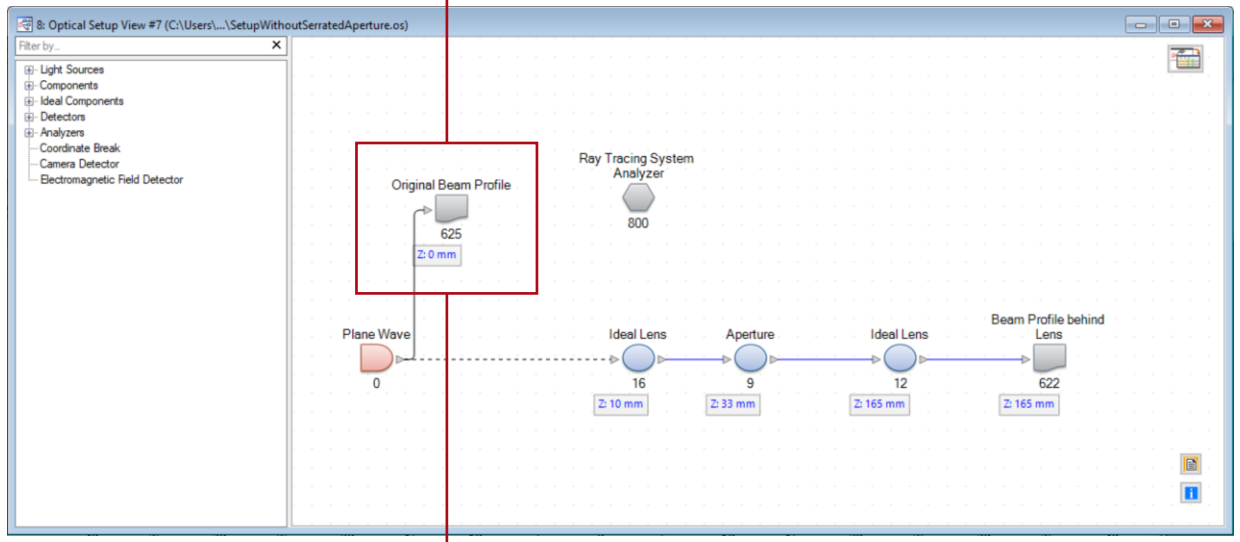


Original Beam Profile

Light view

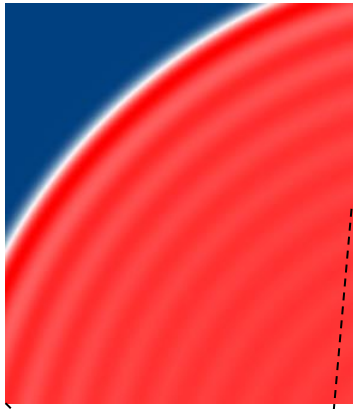




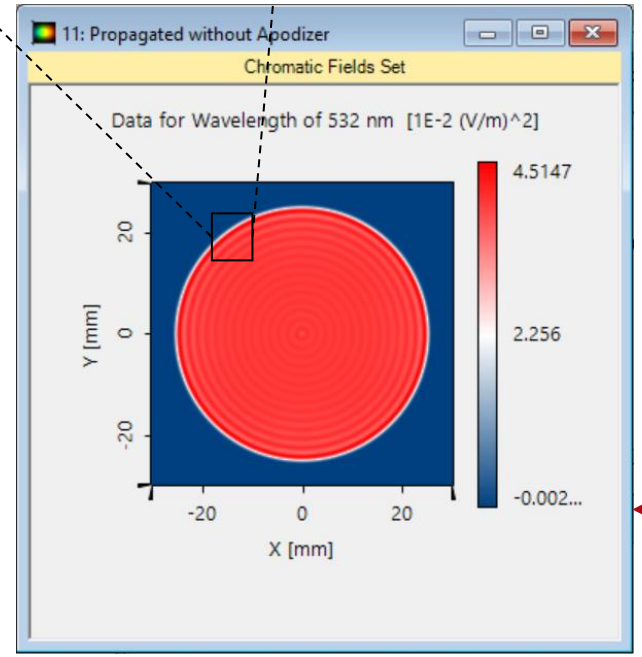


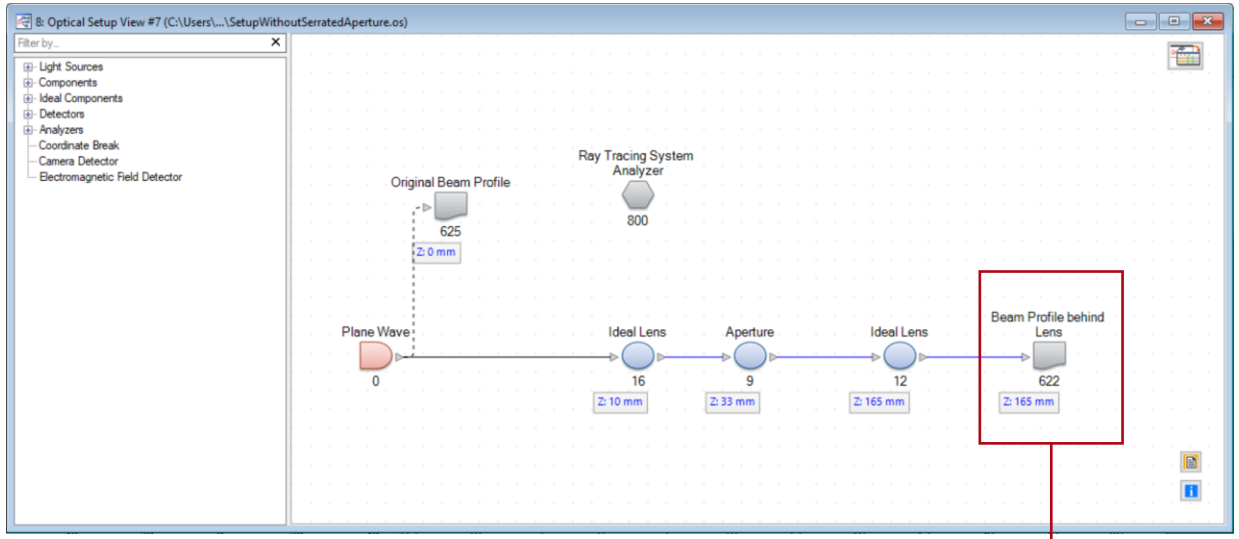
Data view

Propagated Beam Excluding Beam Apodizer



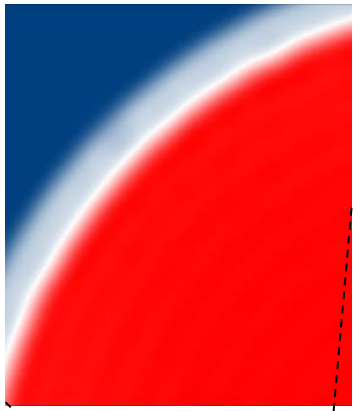
Diffraction ripples are visible.



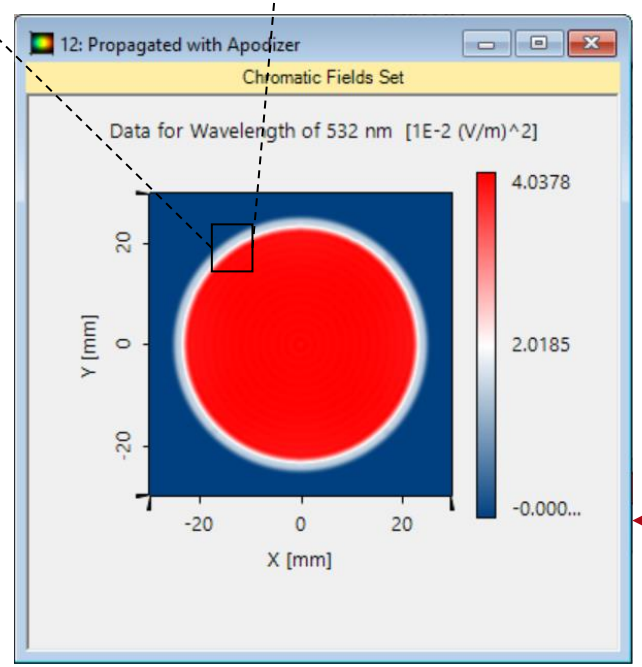


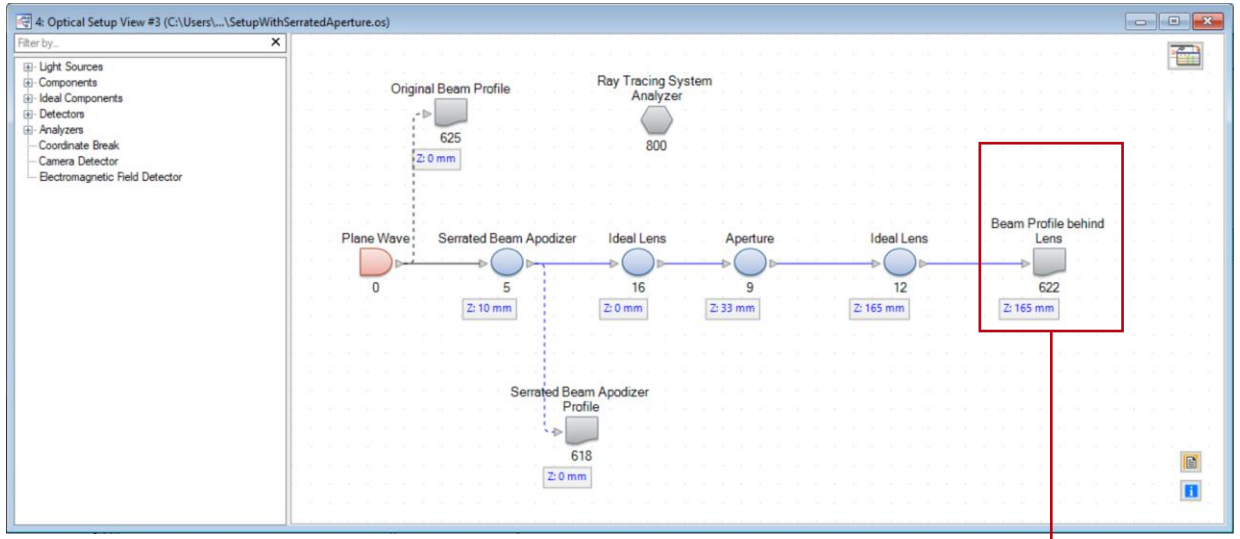
Data view

Propagated Beam Including Beam Apodizer



Diffraction ripples are no longer present.

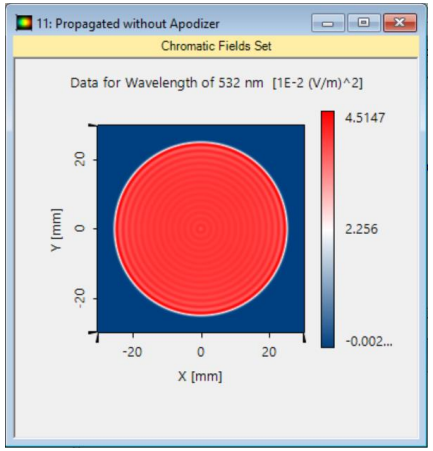


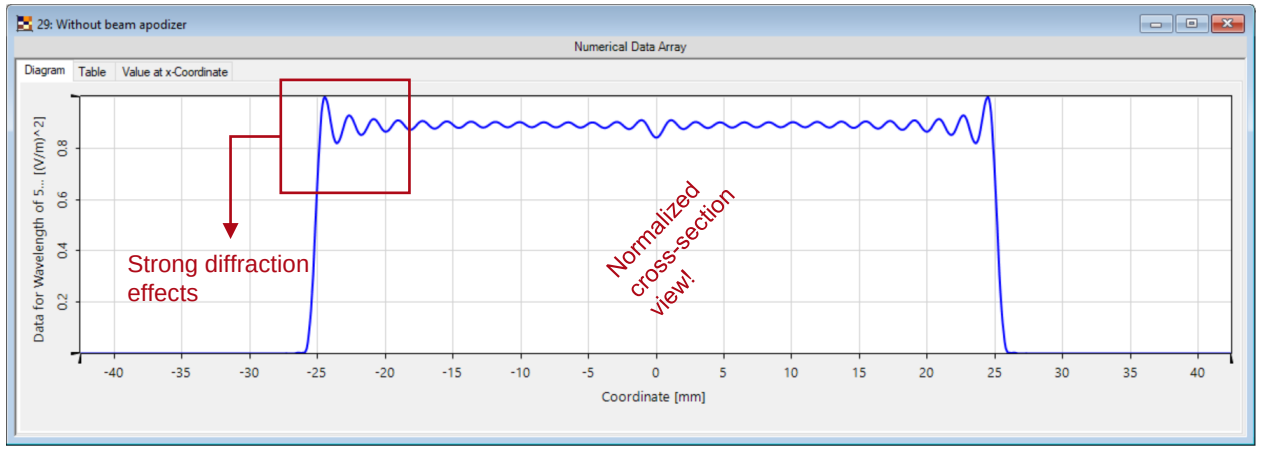


Data view

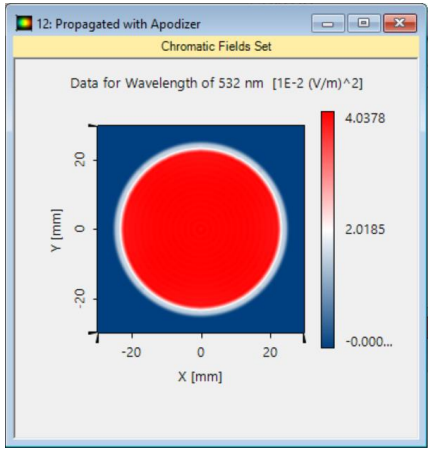
Results Comparison

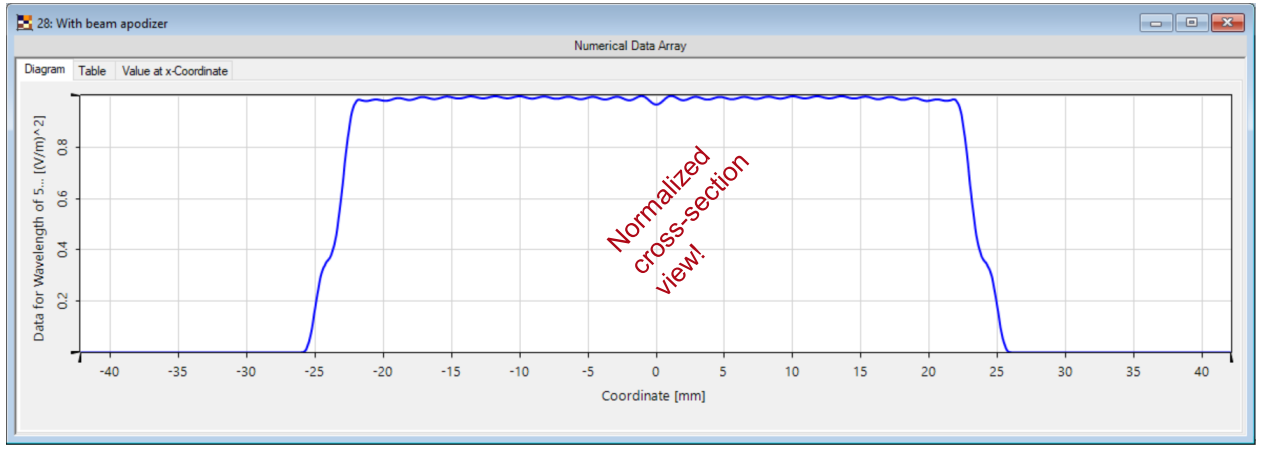
a) Reference Setup





b) Setup with beam apodizer





Comparison with Literature

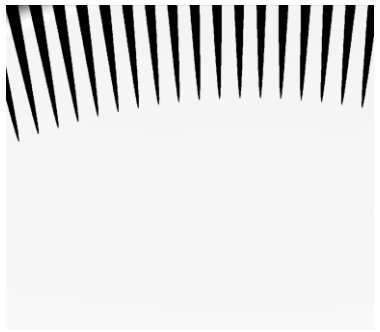
Aperture profile

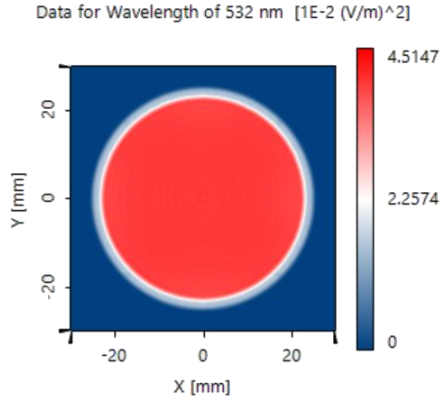
Energy density distribution

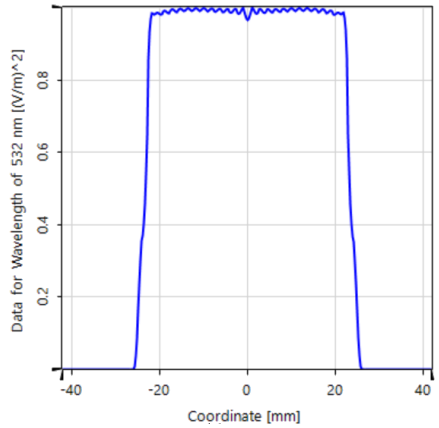
Energy density cross-section view

Aperture Parameters

Shape: Circular
Serrating amplitude: 1 mm
Average radius: 4.5 mm
Number of ridges: 2500







Aperture Parameters

Shape: Rectangular
Serrating amplitude: 1 mm
Outer boundary: 10x10 mm
Number of ridges: ~2500

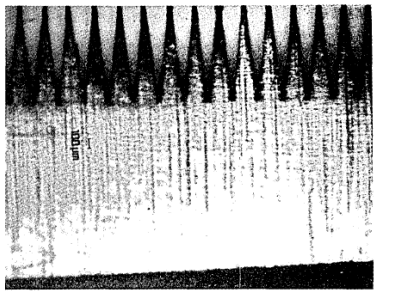
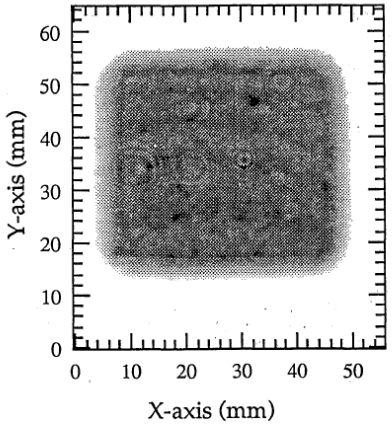
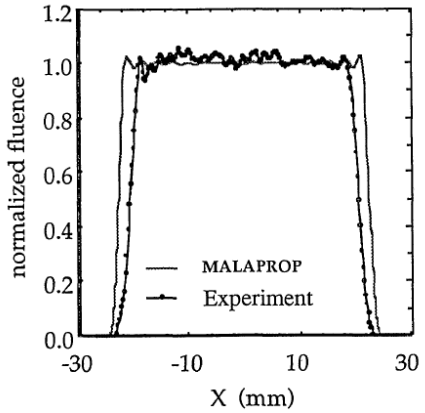


Fig. 4. Photograph of a section of the serrated aperture utilized in the Beamlet laser system. The precision limit on laser cutting has resulted in some roughness on the serrations.





Reference

Jerome M. Auerbach and Victor P. Karpenko, "Serrated-aperture apodizers for high-energy laser systems," Appl. Opt. **33**, 3179-3183 (1994)

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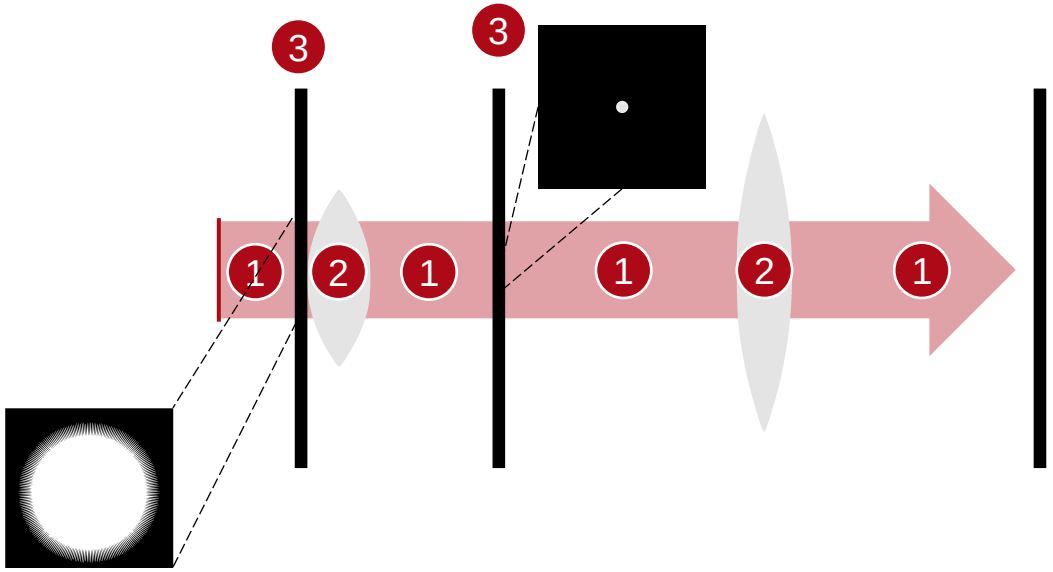

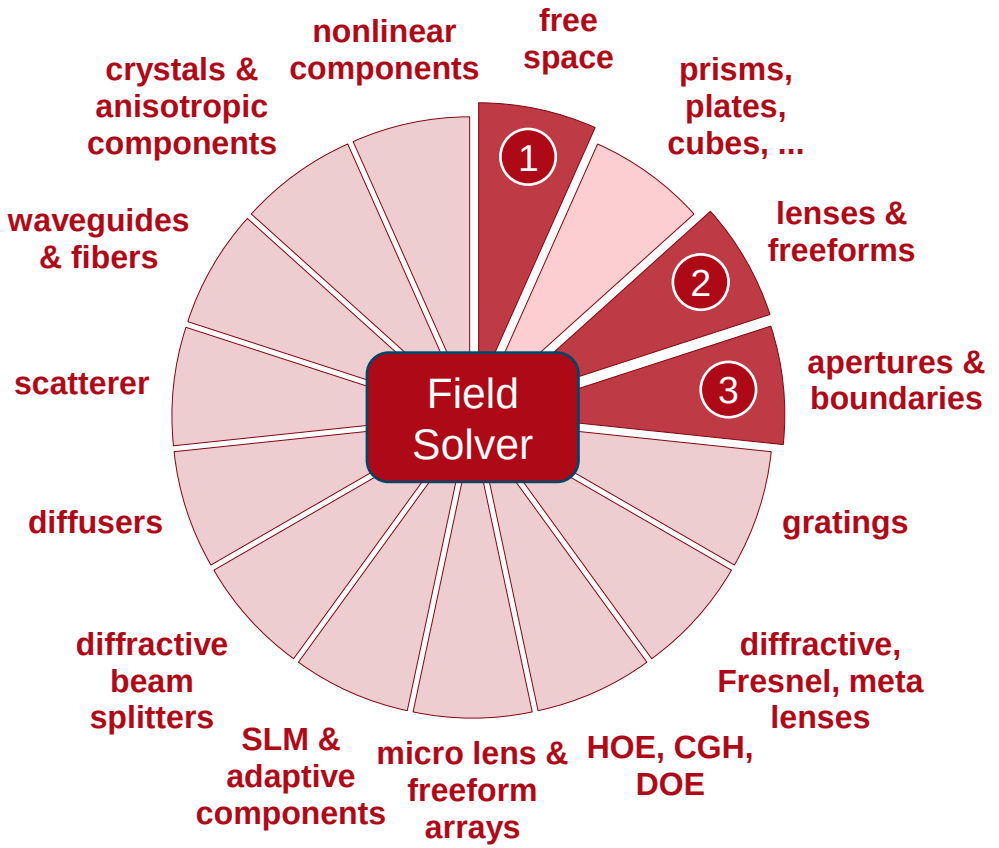

Document Information

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