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# SESAM fabrication errors and its influence on ultrafast laser cavity design

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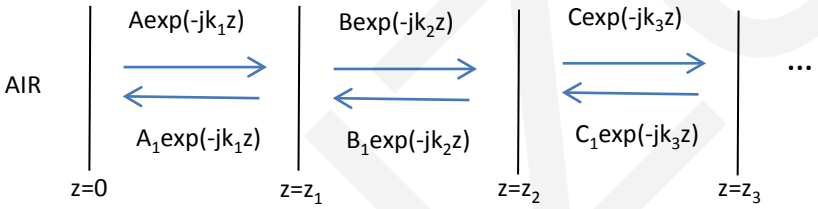
## Why we need to discuss SESAM fabrication error

- SESAM designs and manufacture errors will affect SESAM's optical behavior including GDD, modulation depth and saturantion fluence.
- SESAM's optical behavior will influence ultrafast laser's performance

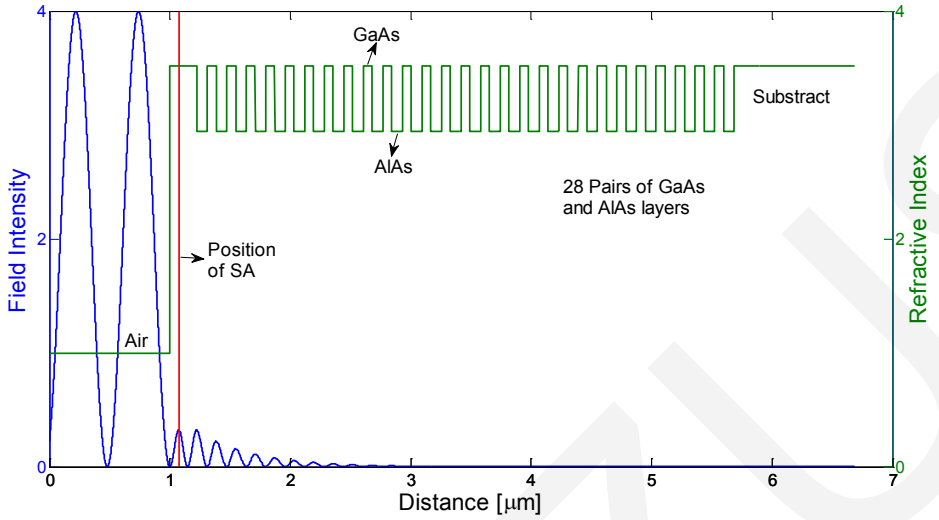
## Transfer Matrix Method will be used to analyze SESAM fabrication error

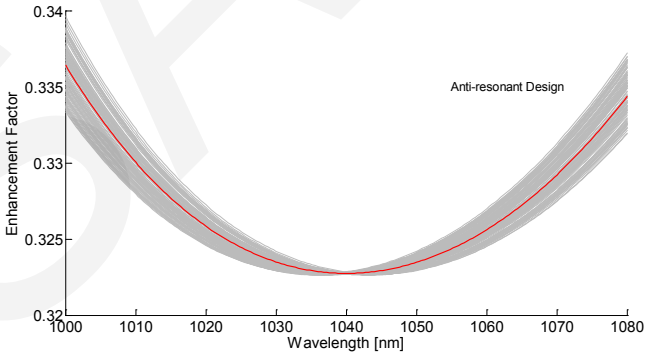


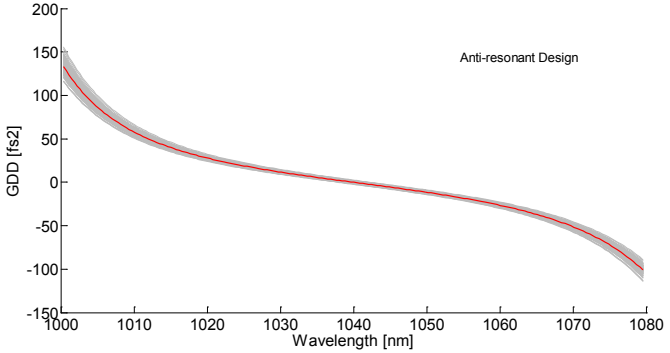

$$\begin{bmatrix} t \\ 0 \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix} \begin{bmatrix} 1 \\ r \end{bmatrix}$$

$$E(n) = E_1 \exp(-jk_n z) + E_2 \exp(jk_n z)$$

# Anti-resonant SESAM

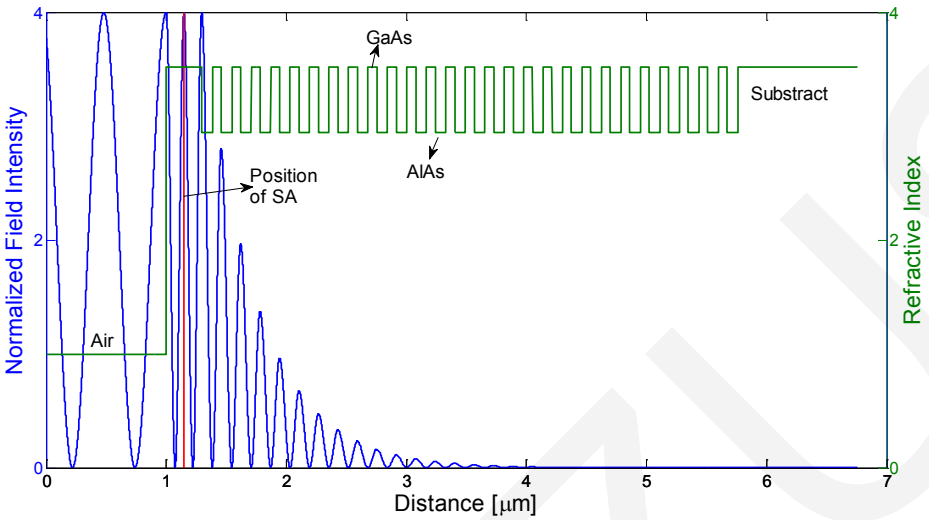


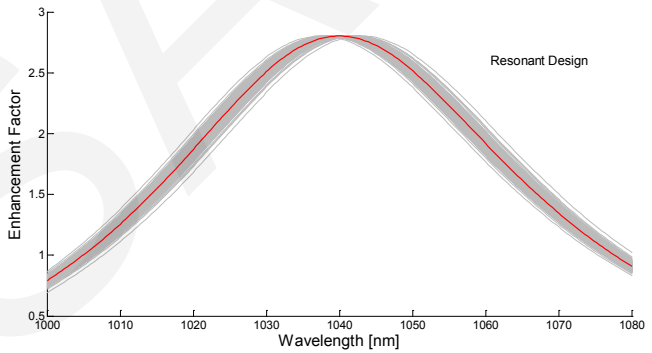



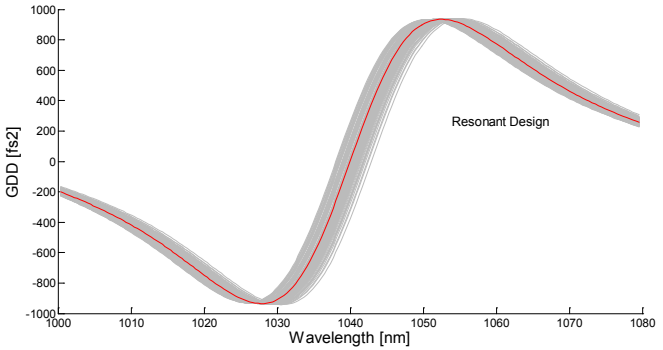




Anti-resonant SESAM structure and wavelength dependent enhancement factor change and GDD change. The red line represents the values for the designed structures assuming no growth errors; the gray lines are calculated with 1% random error for each layer.

# Resonant SESAM

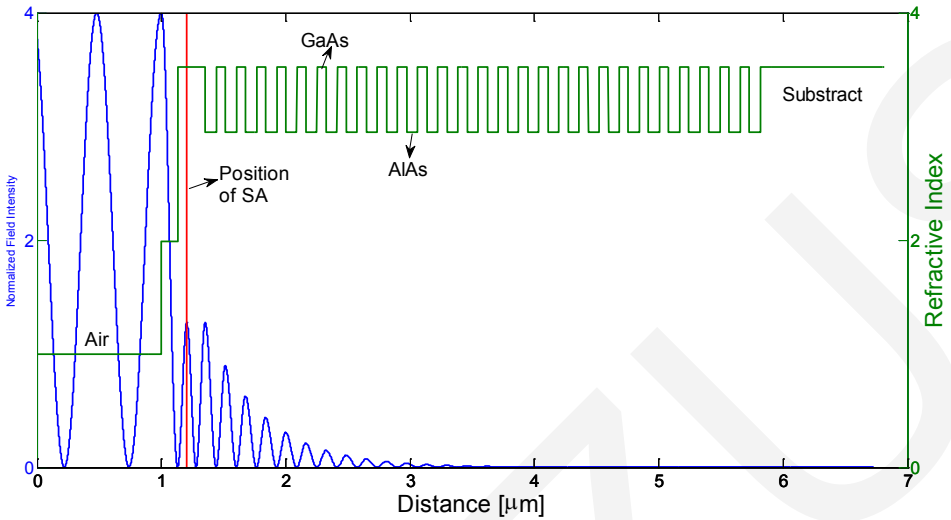


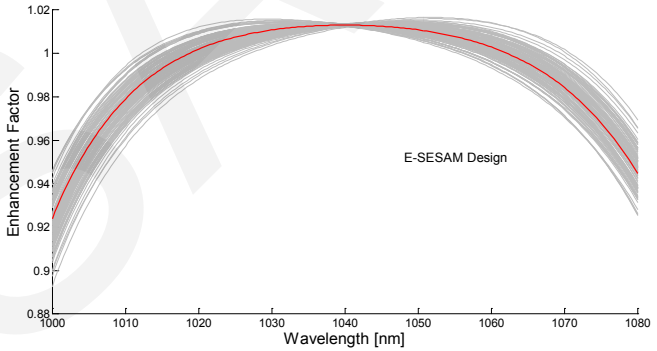



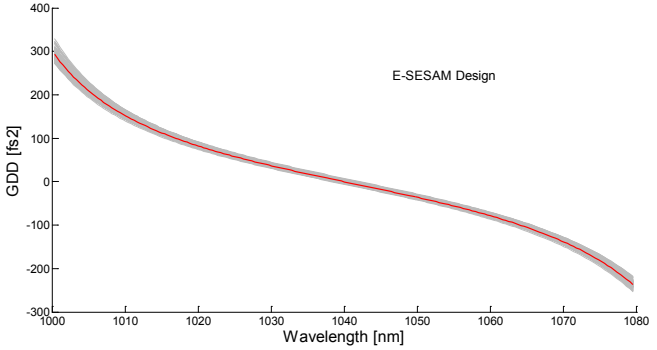




Resonant SESAM structure and wavelength dependent enhancement factor change and GDD change. The red line represents the values for the designed structures assuming no growth errors; the gray lines are calculated with 1% random error for each layer.

# Enhanced SESAM

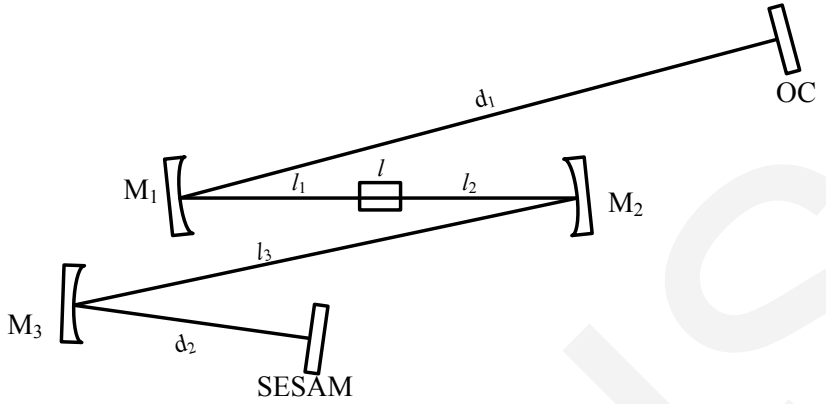



Enhanced SESAM structure and wavelength dependent enhancement factor change and GDD change. The red line represents the values for the designed structures assuming no growth errors; the gray lines are calculated with 1% random error for each layer.

Ultrafast laser cavity design to tolerate fabrication error




Laser running in cw mode locking range needs to satisfy:

$$F_Q = \frac{2q_0\tau_A F_{sat,L} A_{eff,L}}{T_R F_{sat,A} A_{eff,A}} < 1$$

$$F_{QM} = F_{sat,L} A_{sat,L} F_{sat,A} A_{sat,A} \Delta R / E_p^2 < 1$$

Laser cavity length, Laser beam diameter and SESAM beam diameter can be tuned to minimize SESAM's fabrication error influence on ultrafast laser's performance

# Conclusion

1. Fabrication thickness error will affect the characteristics of three SESAM structures: anti-resonant SESAM, resonant SESAM and enhanced SESAM.

2. At the designed center wavelength, a fabrication error does not influence SESAM's modulation depth and saturation fluence that much for all three structures.

3. GDD value is affected a little more in resonant SESAM than in the other two. However if the SESAM is working at an off-center wavelength, the modulation depth error, saturation fluence error and GDD error increase.

4. When designing an ultrafast laser cavity which can tolerate a fabrication error, we should first avoid resonant SESAM, then select the right cavity length (or repetition rate), and make appropriate the curvatures of $M_1$, $M_2$, $M_3$ mirrors (beam sizes on SESAM and gain crystal), and the pumping level to operate the laser running in the CW mode-locking range.