etendue

CASE STUDY: CAVITY ANALYSIS— PRECISION VALIDATION

WHAT IT DOES

The Cavity Analysis plugin calculates the behavior of light trapped between mirrors in a laser resonator. It predicts beam size, divergence, stability, and thermal effects — the essential parameters for designing any laser cavity.

HOW IT WORKS

Light bouncing between curved mirrors forms a stable beam only under certain conditions. The plugin uses standard optical formulas (ABCD matrices) to find the natural "eigenmode" — the beam shape that reproduces itself after each round trip.

For thermal effects, it calculates how absorbed pump power creates a lens inside the gain medium, which can destabilize the cavity if not accounted for.

VALIDATION APPROACH

We compared our calculations against the RP Photonics Encyclopedia, the industry-standard reference used by laser engineers worldwide. 15 validation points were tested against their published calculator values and formulas.

ACCURACY SUMMARY

CATEGORY	PARAMETER	FORMULA	MIN
THERMAL LENS	Focal length f	$f = \pi K w^2/(dn/dT \cdot P)$	0.27%
GAUSSIAN BEAM	z_R, θ, BPP	$z_R = \pi w_o^2/\lambda$	0.09%
CAVITY FINESSE	Finesse F	$F = \pi\sqrt{R}/(1-R)$	0.01%
APERTURE CLIPPING	Transmission T	$T = 1-e^{(-2(a/w)^2)}$	0.004%
CAVITY STABILITY	g-parameter	$g = 1-L/R$	0.00%

Global precision: Mean error = 0.11% across all validation points.

PHYSICAL VALIDITY

MODEL	VALID RANGE	LIMITS
THERMAL LENS	P: 0.1–1000 W, w: 10–2000 µm	Nd:YAG, Ti:Sapphire, Yb:YAG
GAUSSIAN BEAM	λ: 200–15000 nm, w_o: 1 µm–50 mm	Paraxial: $w_o > 10\lambda$
STABILITY	L: 1–10000 mm	$0 < g_1g_2 < 1$

BUILT-IN SAFETY CHECKS

The plugin warns you when:

- Your cavity is near instability boundaries ($g_1g_2 < 0.01$ or > 0.99)
- Beam waist violates paraxial approximation ($w_o < 10\lambda$)
- Apertures might clip your beam ($a/w < 2$)

REFERENCES

Kogelnik & Li (1966) • Siegman, *Lasers* (1986) • RP Photonics Encyclopedia (DOI: 10.61835)