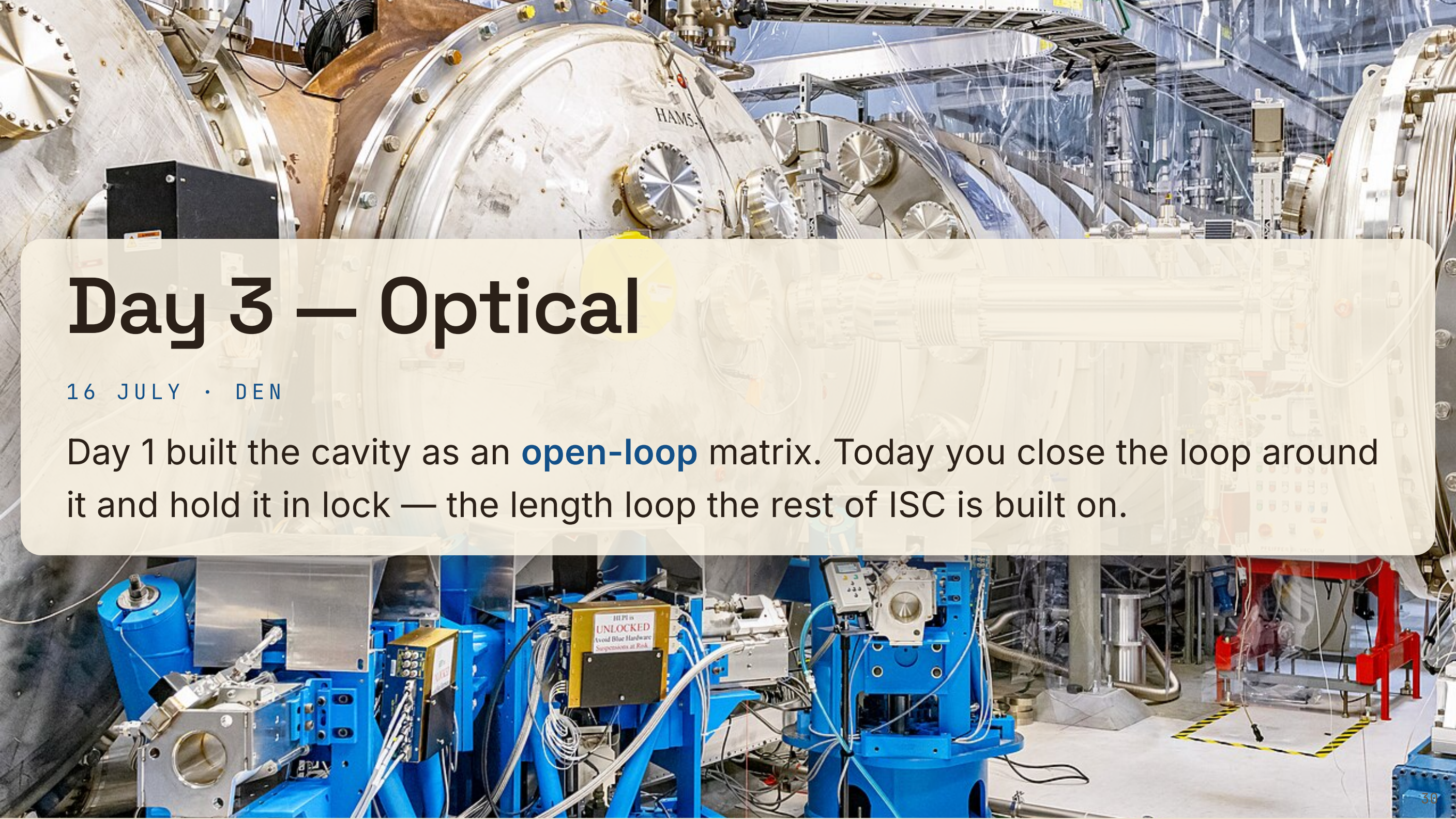
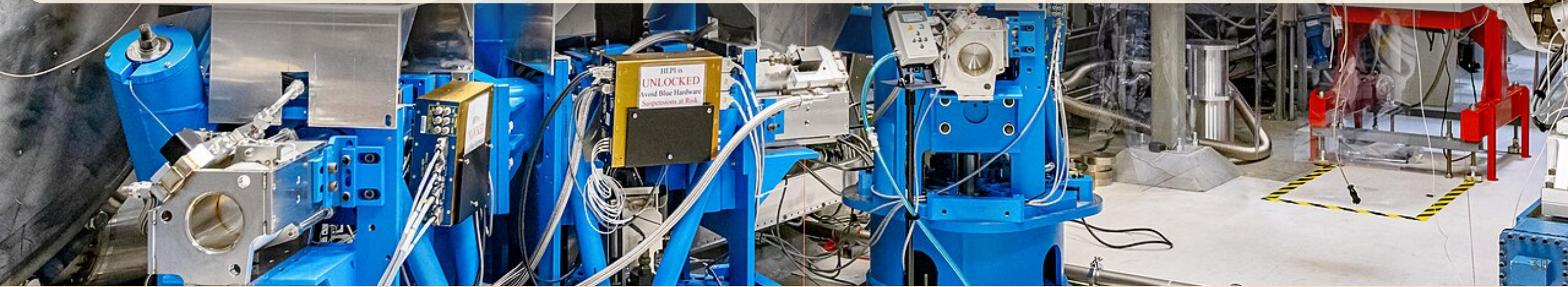




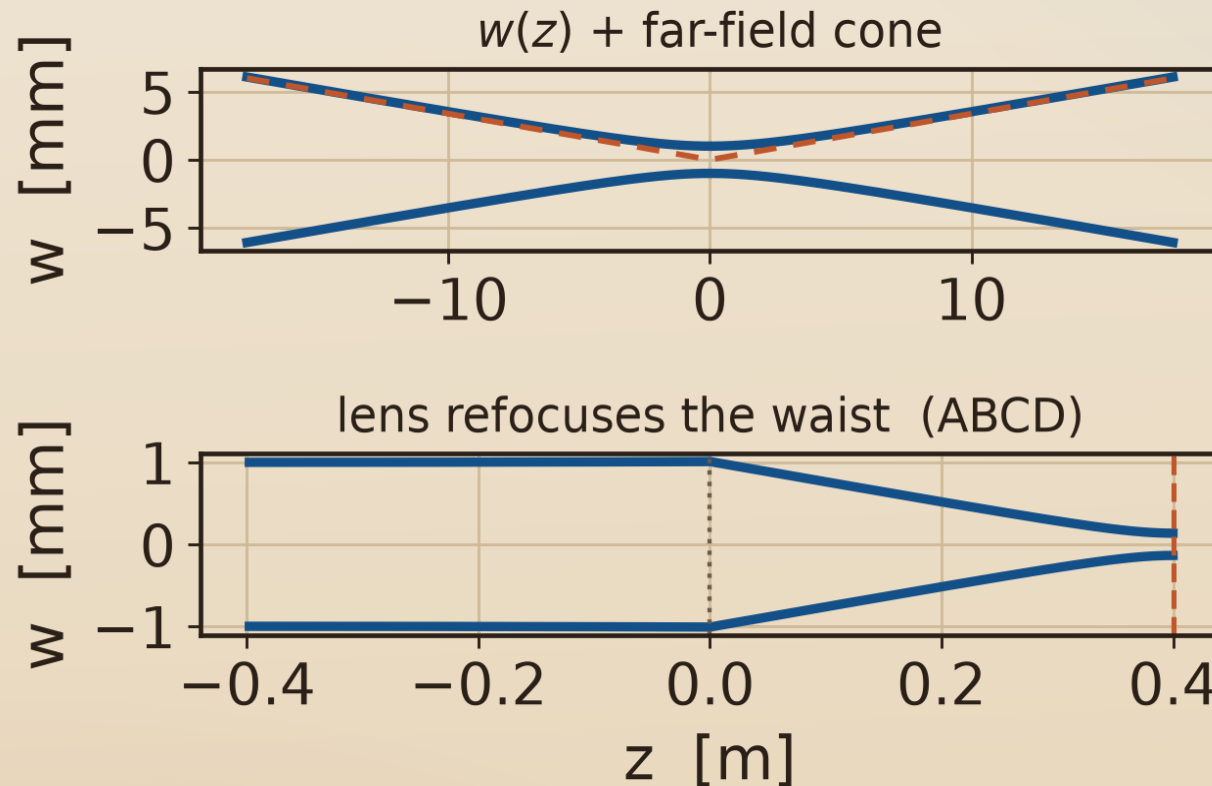
Day 3 — Optical

16 JULY • DEN

Day 1 built the cavity as an **open-loop** matrix. Today you close the loop around it and hold it in lock — the length loop the rest of ISC is built on.



The beam is one number q



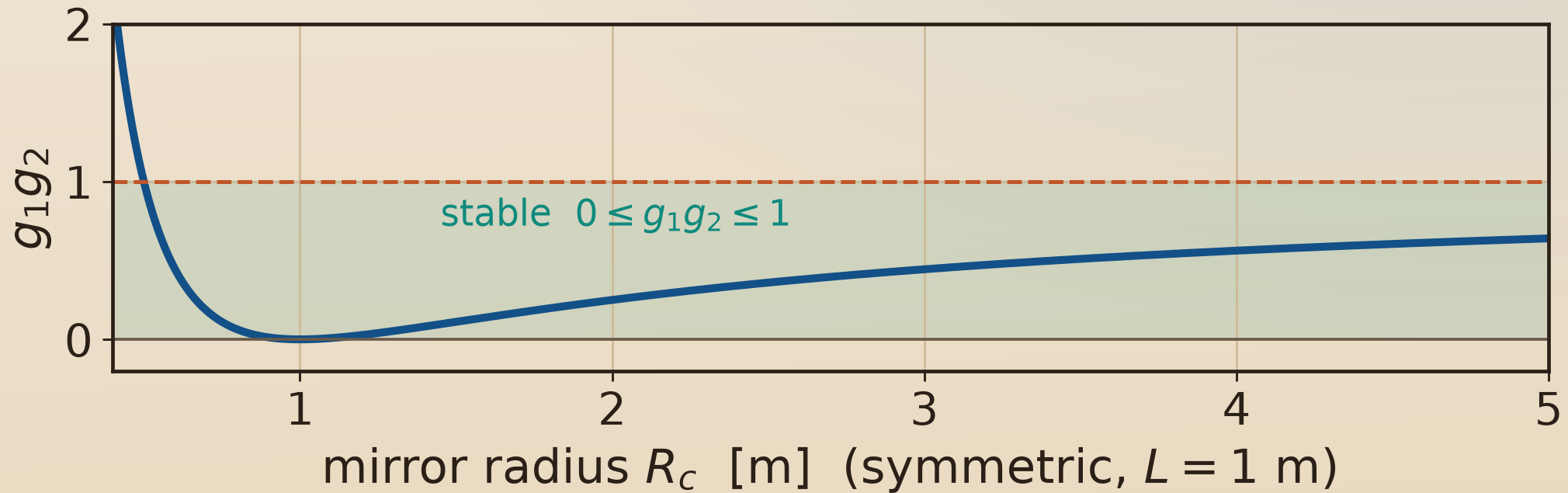
A Gaussian beam is one complex number,

$$q = z + iz_R, \quad \frac{1}{q} = \frac{1}{R} - i \frac{\lambda}{\pi w^2}.$$

$w(z) = w_0 \sqrt{1 + (z/z_R)^2}$ opens into a cone $\theta = \lambda/\pi w_0$; $R(z) = z + z_R^2/z$. Each optic is an **ABCD** matrix and moves the beam by $q' = (Aq + B)/(Cq + D)$ — a lens reforms the waist f downstream. That is a mode-matching telescope.

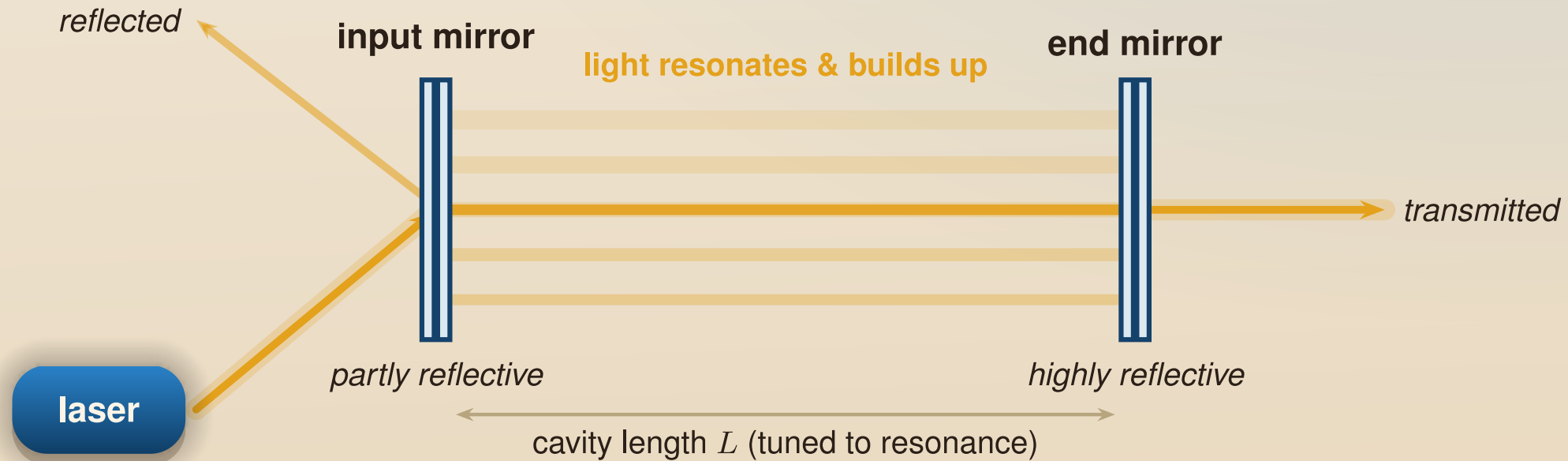
Kogelnik & Li, Appl. Opt. 5, 1550 (1966); Siegman, *Lasers*. Computed from M6.

Cavity stability and Gouy phase



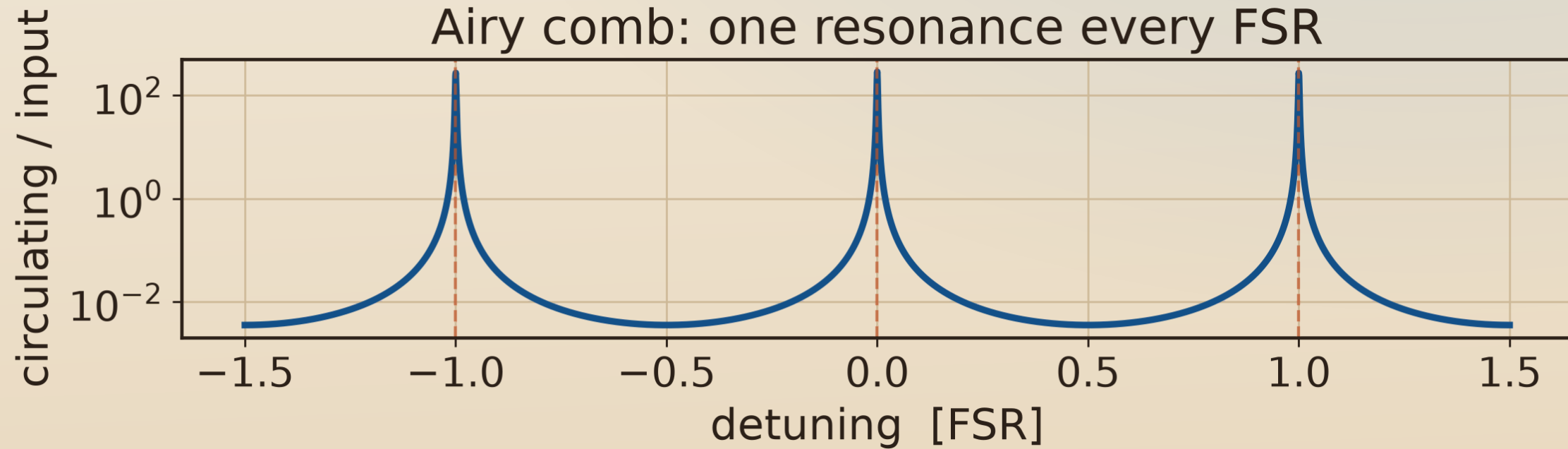
$g_i = 1 - L/R_i$. A cavity holds a stable mode only for $0 \leq g_1 g_2 \leq 1$. The round-trip matrix also sets the **round-trip Gouy phase**, which fixes where the higher-order modes sit relative to the carrier — the spacing Thursday's wavefront sensors read.

Light builds up: the cavity



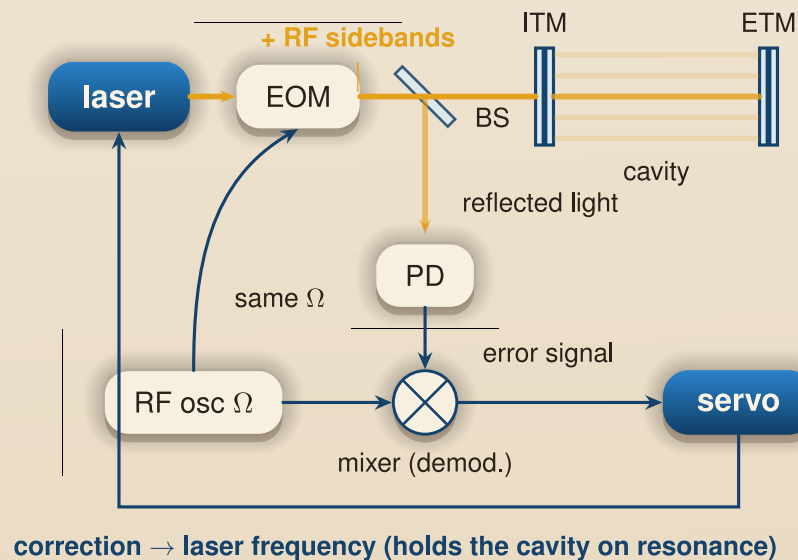
A **Fabry-Pérot** cavity: light injected on resonance builds up between the mirrors — one optical pole, the plant you will lock.

FSR, finesse, linewidth, Airy

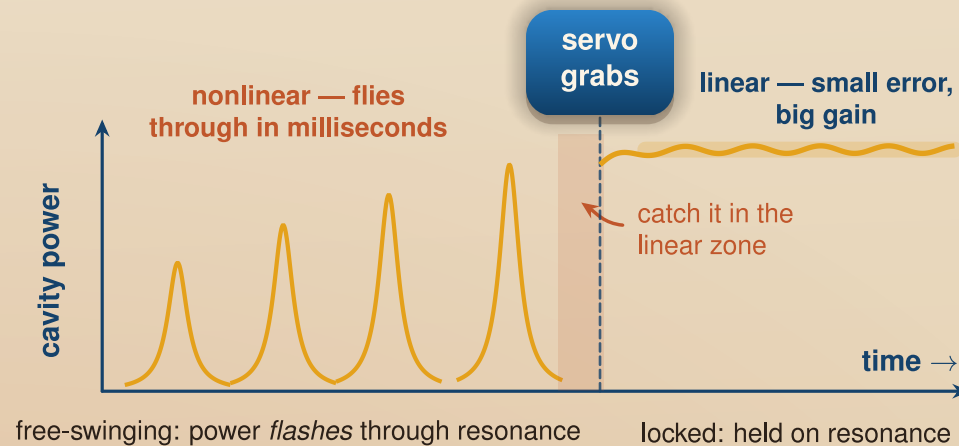


$\text{FSR} = c/2L$, finesse $F = \pi\sqrt{r_1 r_2}/(1 - r_1 r_2)$, linewidth = FSR/F . The buildup peak repeats every FSR — the comb behind the “detuning [FSR]” axis.
Arm ($L = 4$ km): $\text{FSR} \approx 37.5$ kHz, $F \approx 445$, linewidth ≈ 84 Hz, buildup $\approx 280\times$, pole ≈ 42 Hz.

Day 3 · afternoon — lock the cavity



lock acquisition: catch a flash, then hold — nonlinear → linear



"Lock the cavity" twin

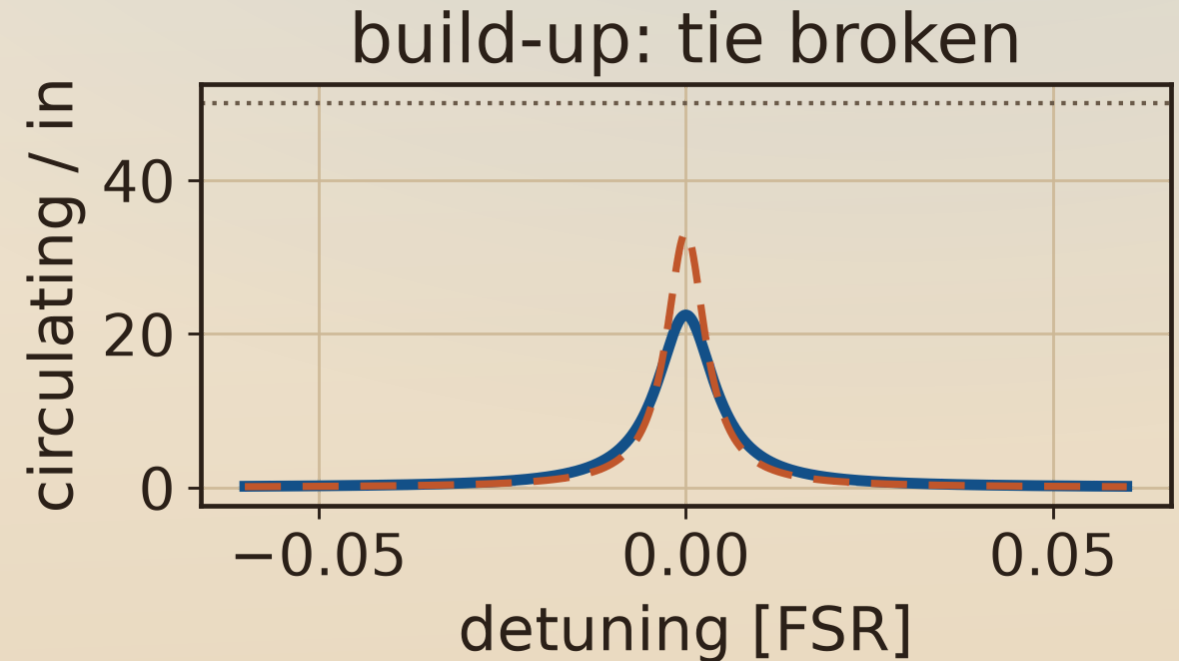
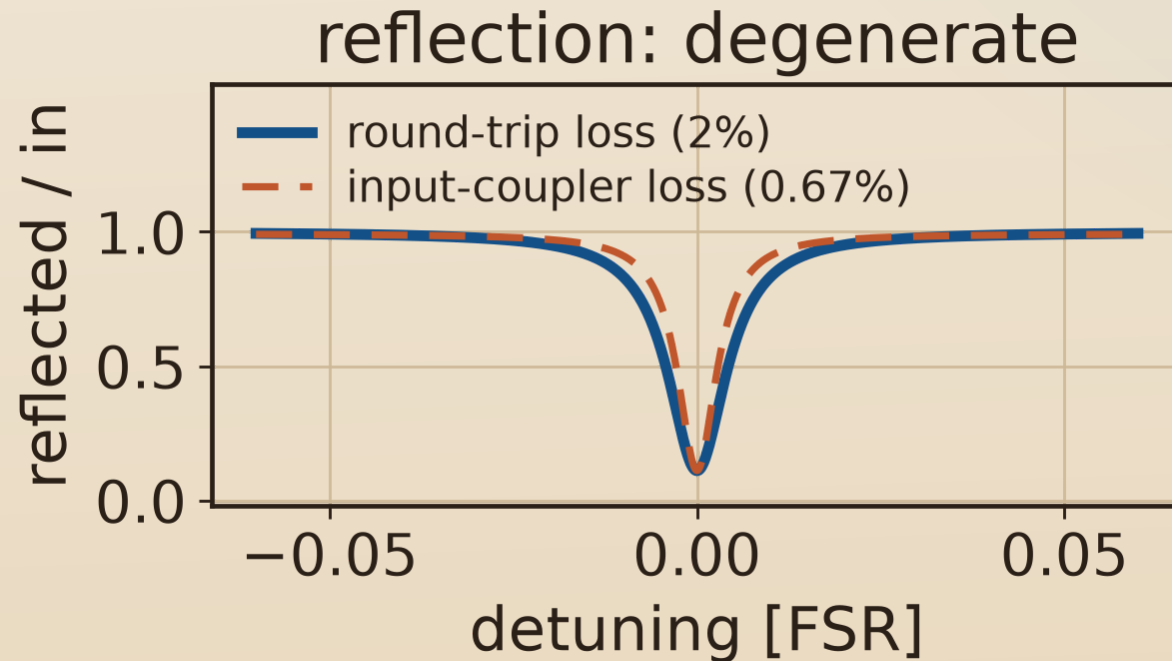
1. Sweep — form the **PDH discriminant**
2. Close the loop — acquire and hold **lock**
3. See what limits it — loop gain, loop noise

FIRST DISCREPANCY

A companion cavity has extra loss — measurement disagrees with your prior. Localize it, then judge whether it costs you anything.

Deliverable · locked cavity + loss diagnosis

Localizing the loss — reflection is degenerate



Low buildup means loss — but input-coupler loss, round-trip loss, **and** mode mismatch all lower it, and reflected power alone cannot separate them: 2% round-trip loss and 0.67% coupler loss give the **identical** dip. A **second** measurement breaks the tie — the build-up does (22× vs 33×, against 50× for the matched cavity).

Whether the loss *matters* is a budget call