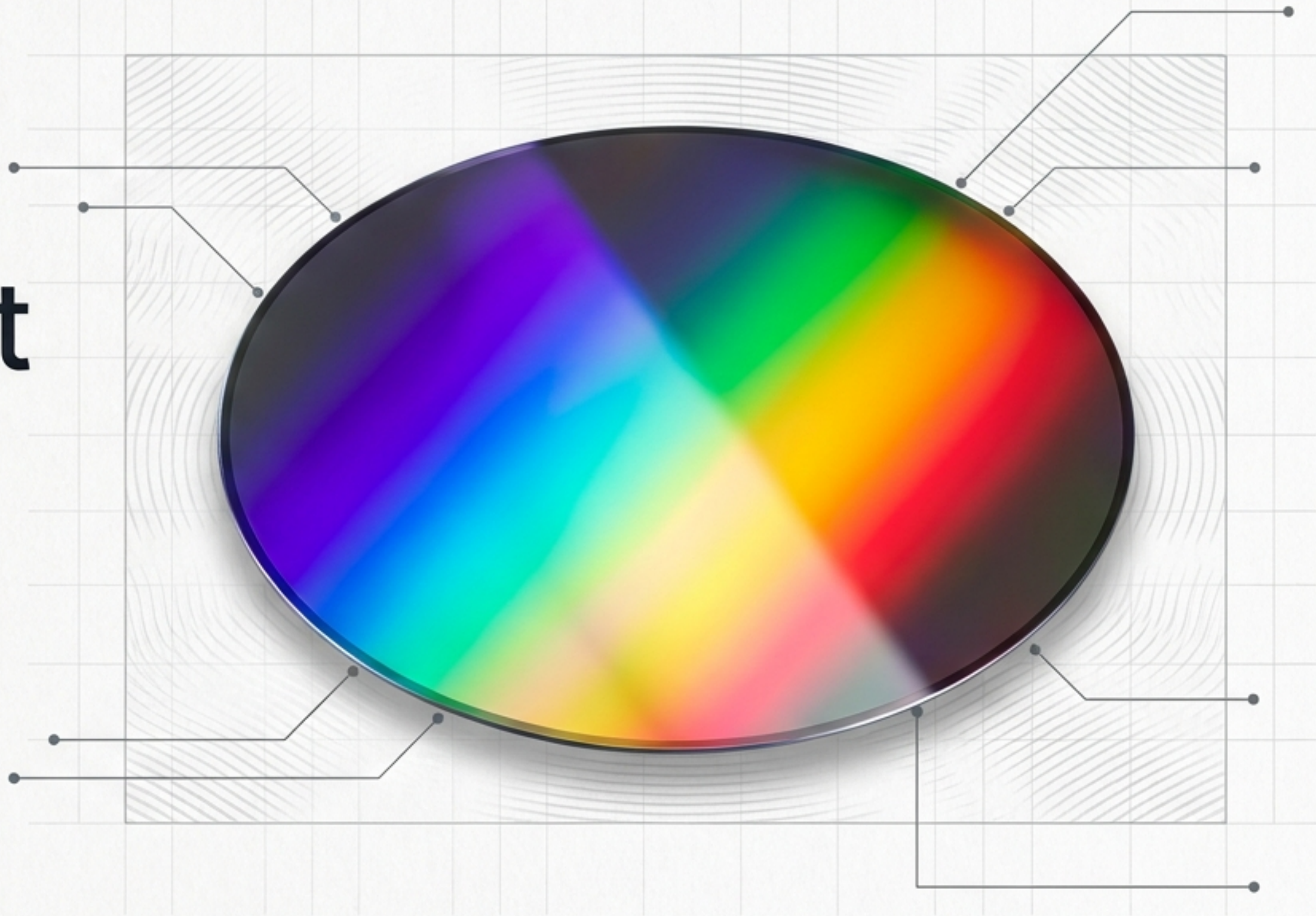


# Taming Light in Silicon

The Chisel and  
the Paintbrush



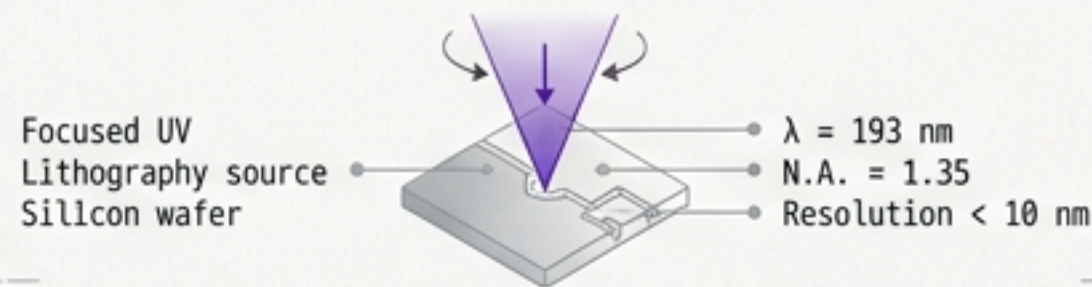
IN PURSUIT OF THE NANOMETER SCALE // MASTERING DIFFRACTION AND EMISSION



# “What marks the height of a civilization is the grandest engineering it can build by commanding the forces of nature.”

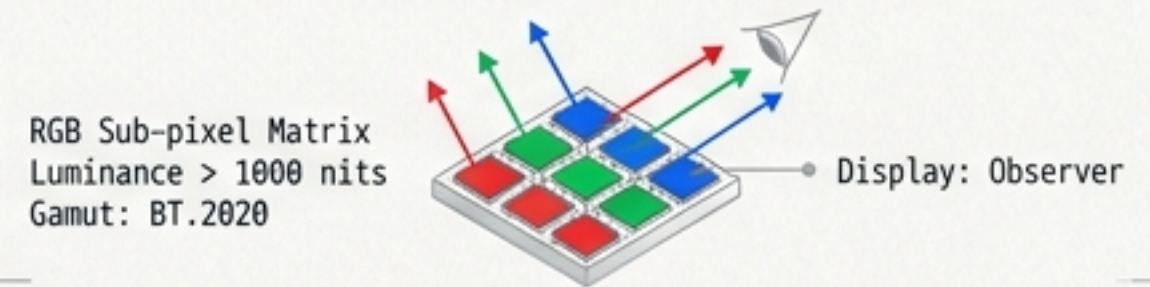
## Light as the Chisel.

Carving microscopic circuits into slabs of silicon.



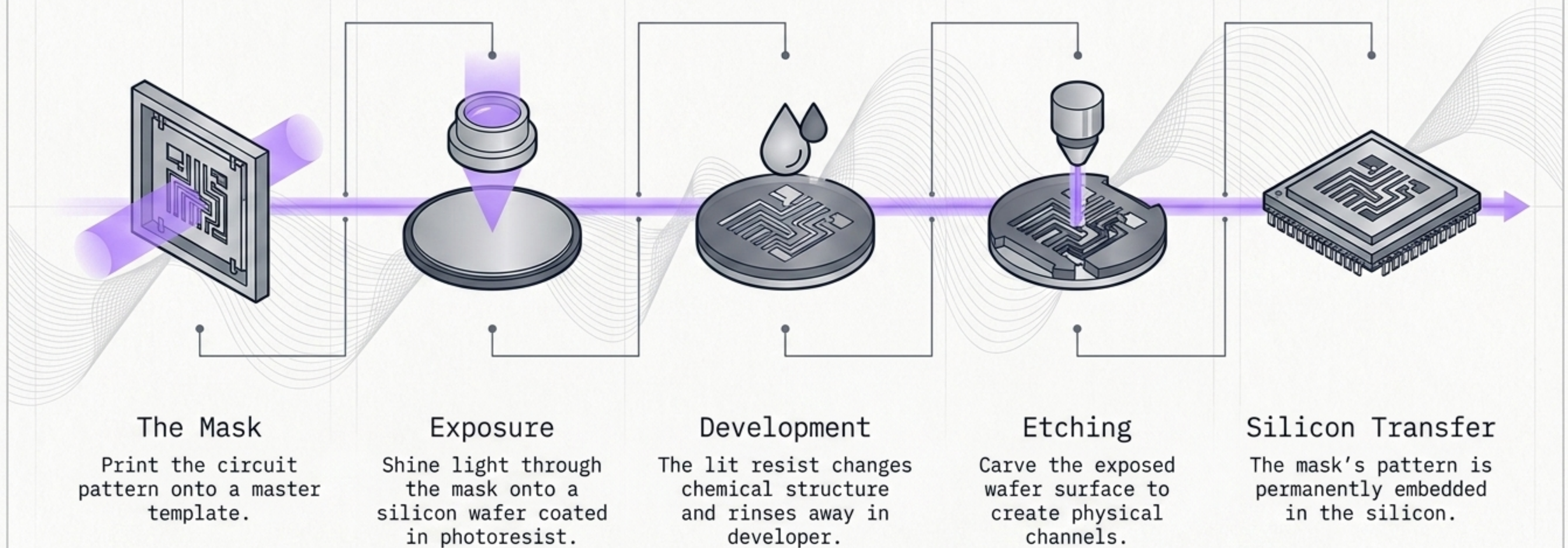
## Light as the Paintbrush.

Emitting photons to build modern screens.





# Drawing Circuits with Light



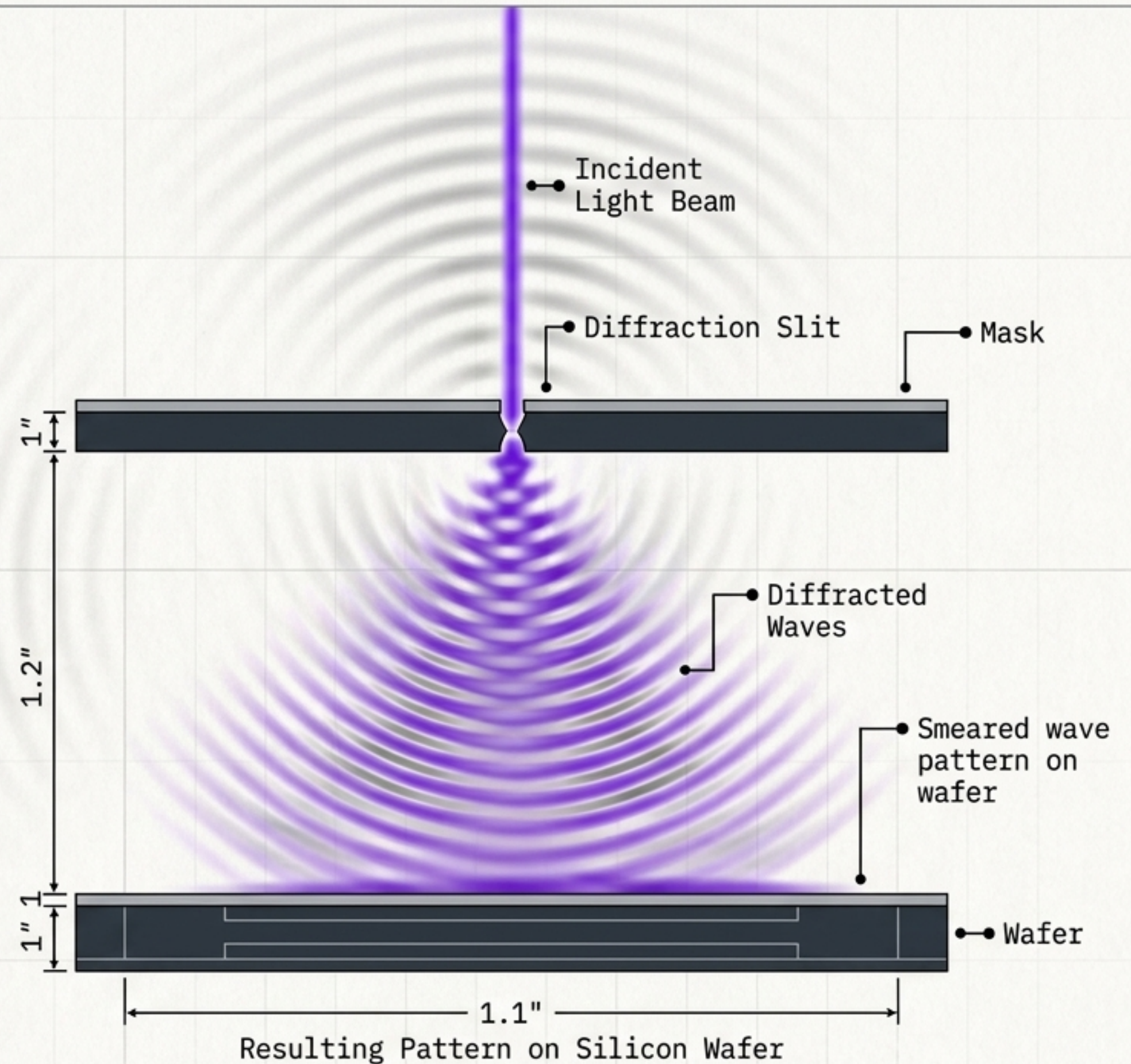


# The Enemy: Diffraction

You want it fine, physics smears it out.

Light is a wave. When forced through a narrow nanometer slit in a mask, it refuses to travel in a tidy straight line. It diffracts, fanning out to the sides.

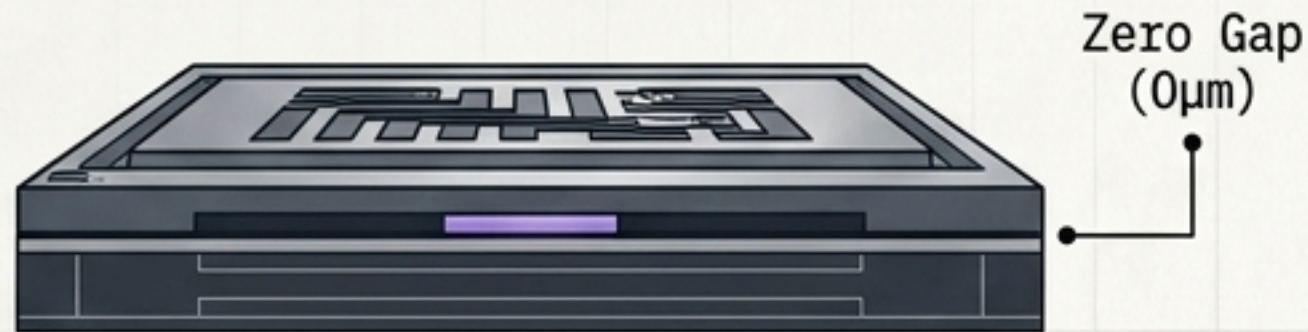
The narrower the target circuit, the wider the smear on the silicon below.





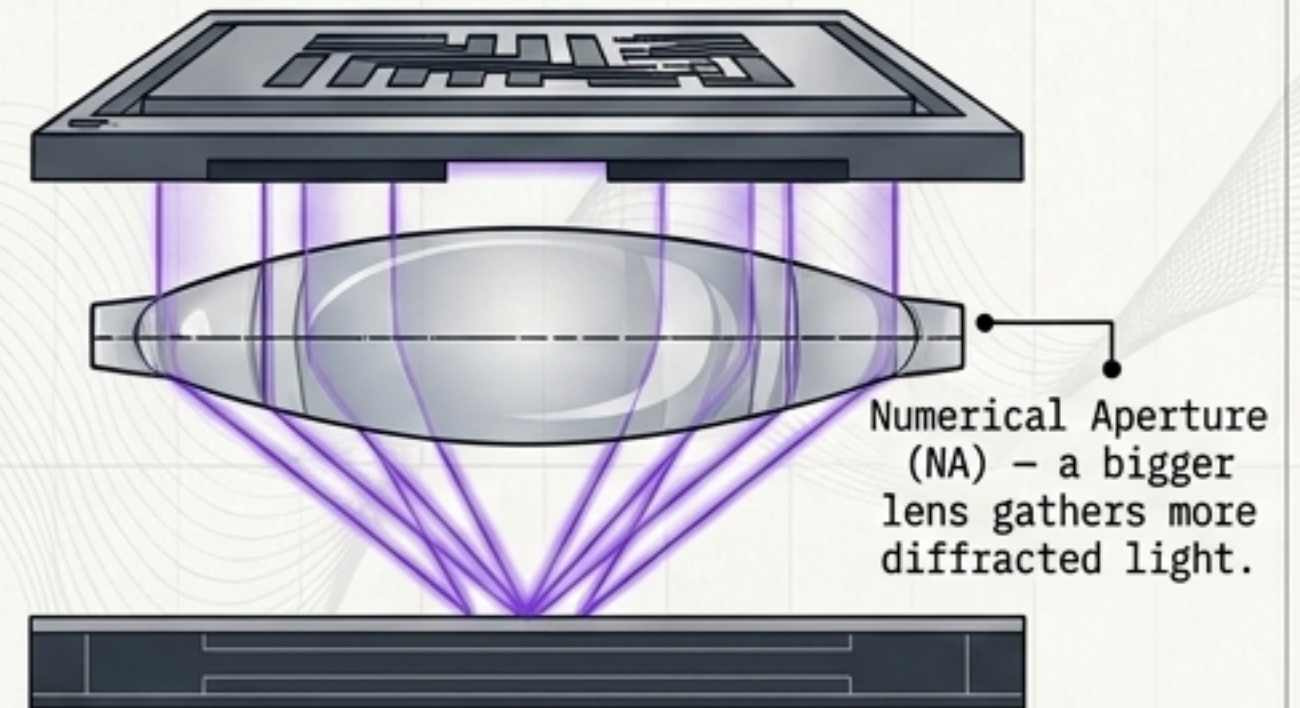
# Two Tactical Paths to Fight the Smear

## Proximity Lithography



Keep the wafer pressed directly against the mask. Expose before the light has physical space to spread.

## Projection Lithography



Back the wafer off and insert a convex lens. Shrink the mask's pattern onto the wafer.

## The Ultimate Fix: Shorten the Wavelength

436nm — 248nm — 193nm (Immersion) — The 13.5nm Leap



# The 1nm Dead End: An X-Ray Autopsy

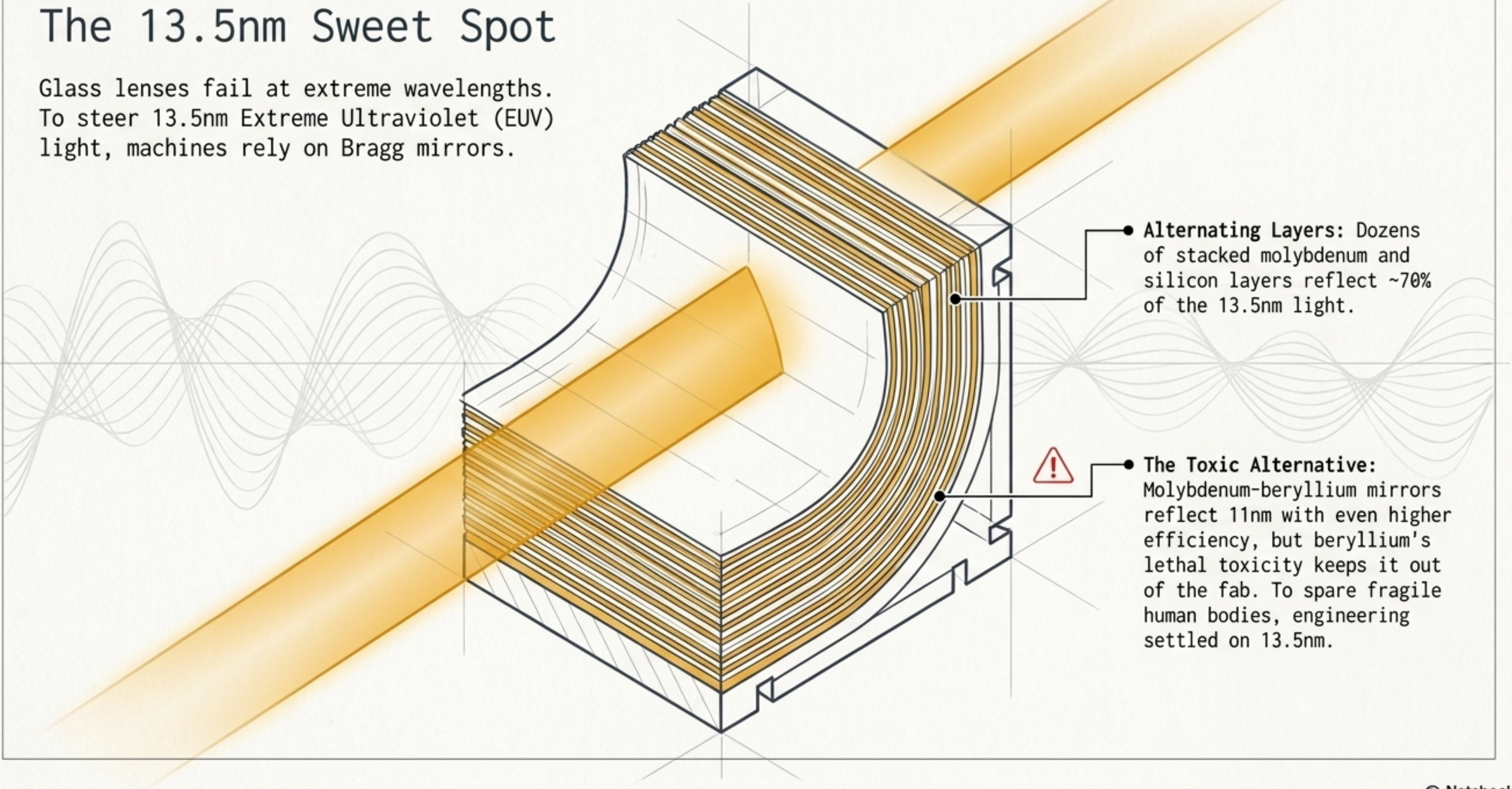
|                  |                                                                                                                                   |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| The Promise      | 1nm wavelength suppresses diffraction almost entirely.                                                                            |
| The Reality      | X-rays ignore glass. No lenses means forced 1:1 proximity lithography. 10nm chips require brutally difficult 10nm mask precision. |
| The Instability  | Operates in the near-field diffraction zone. A mere 1-micron gap change completely scrambles the pattern.                         |
| The Mask Failure | Gold mask patterns absorb X-rays, turning them into heat. The endless expansion and contraction eventually cracks the gold film.  |

"X Ray works for the dentists."  
— Burn-Jeng Lin (IBM, dismissing the X-ray team's celebratory t-shirts).



# The 13.5nm Sweet Spot

Glass lenses fail at extreme wavelengths. To steer 13.5nm Extreme Ultraviolet (EUV) light, machines rely on Bragg mirrors.

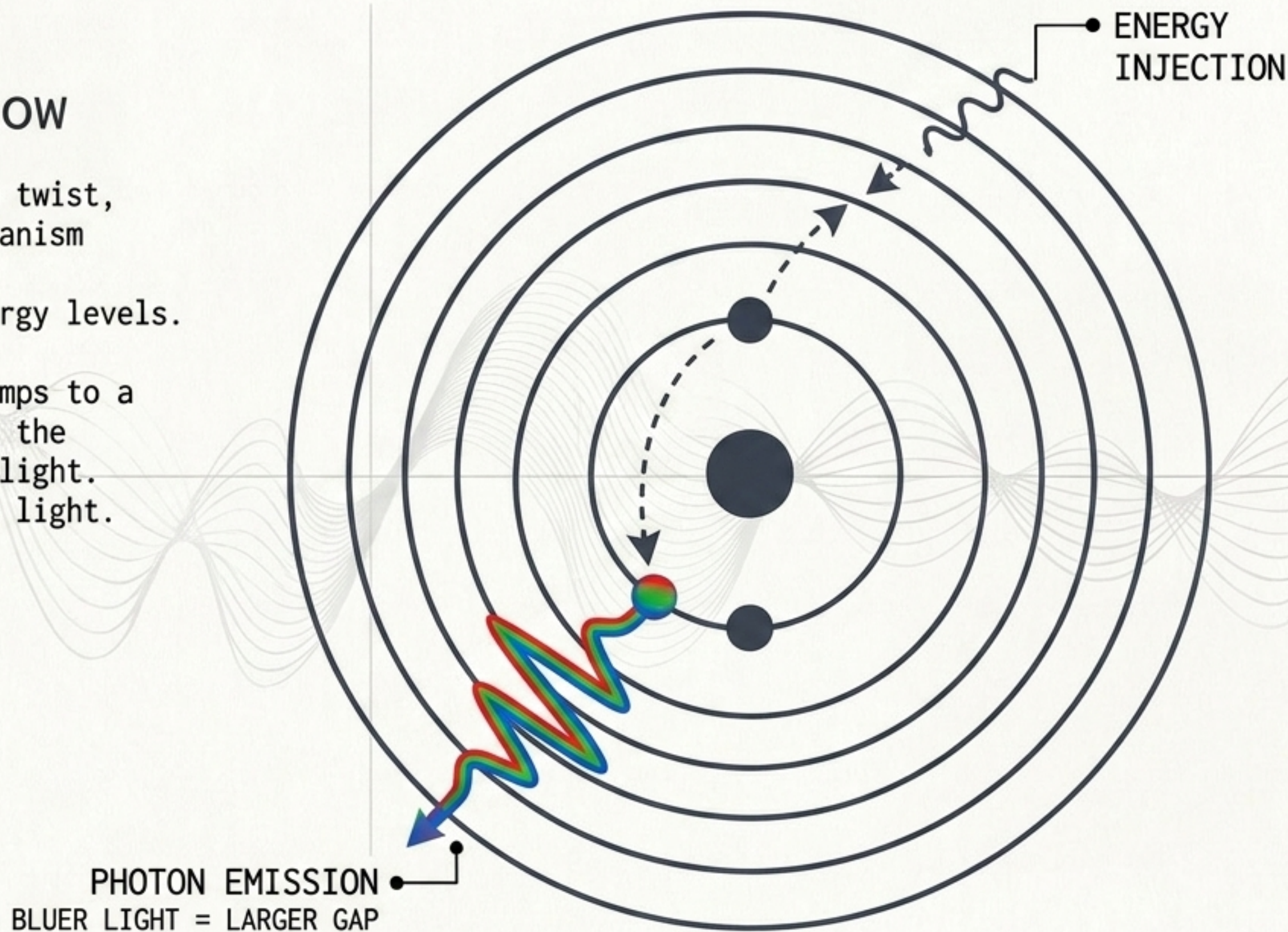




# The Paintbrush: Making Silicon Glow

Light can carve chips, but with a twist, it can glow. The fundamental mechanism of display technology relies on manipulating electrons across energy levels.

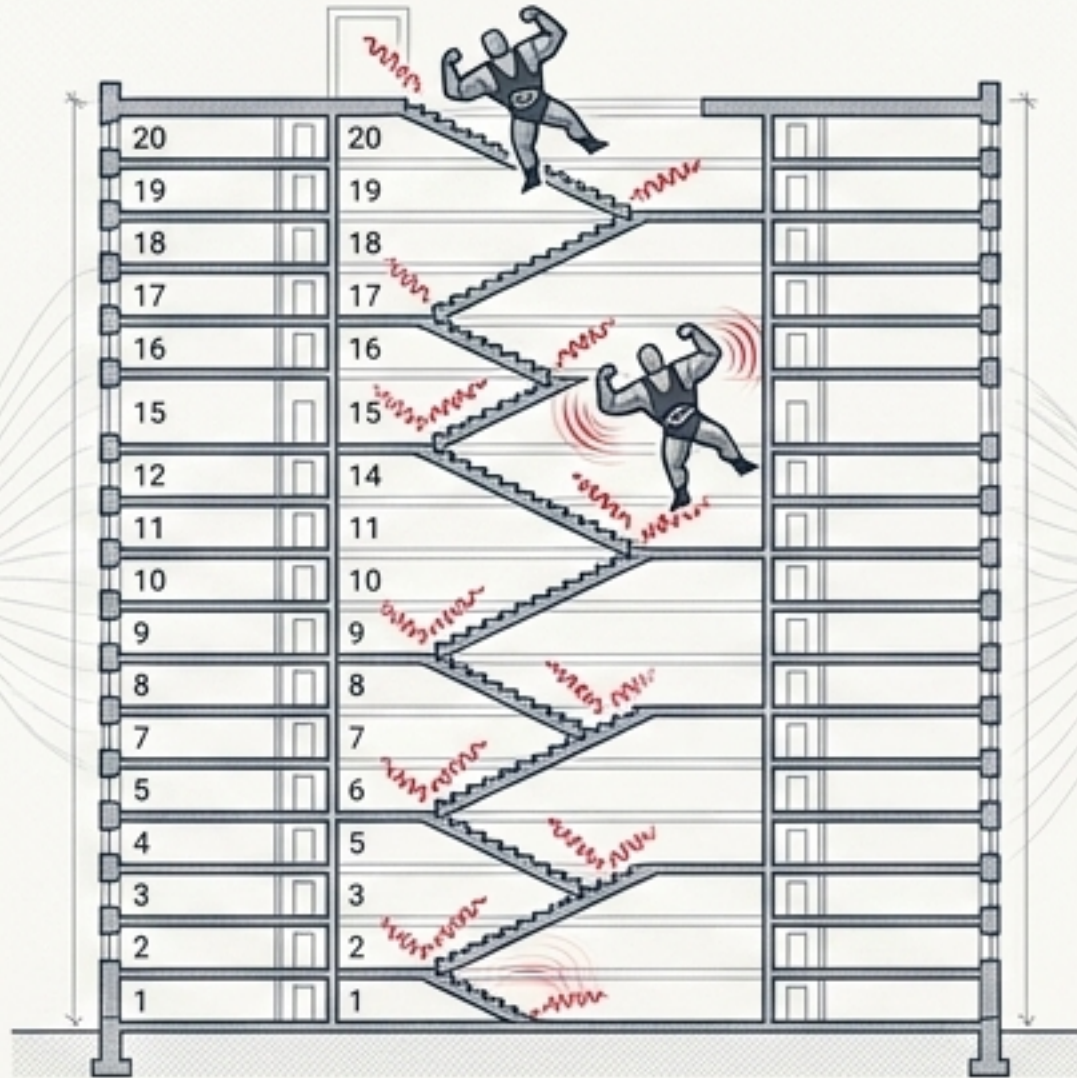
Inject energy, and an electron jumps to a higher level. When it falls back, the energy difference is expelled as light. The bigger the gap, the bluer the light.





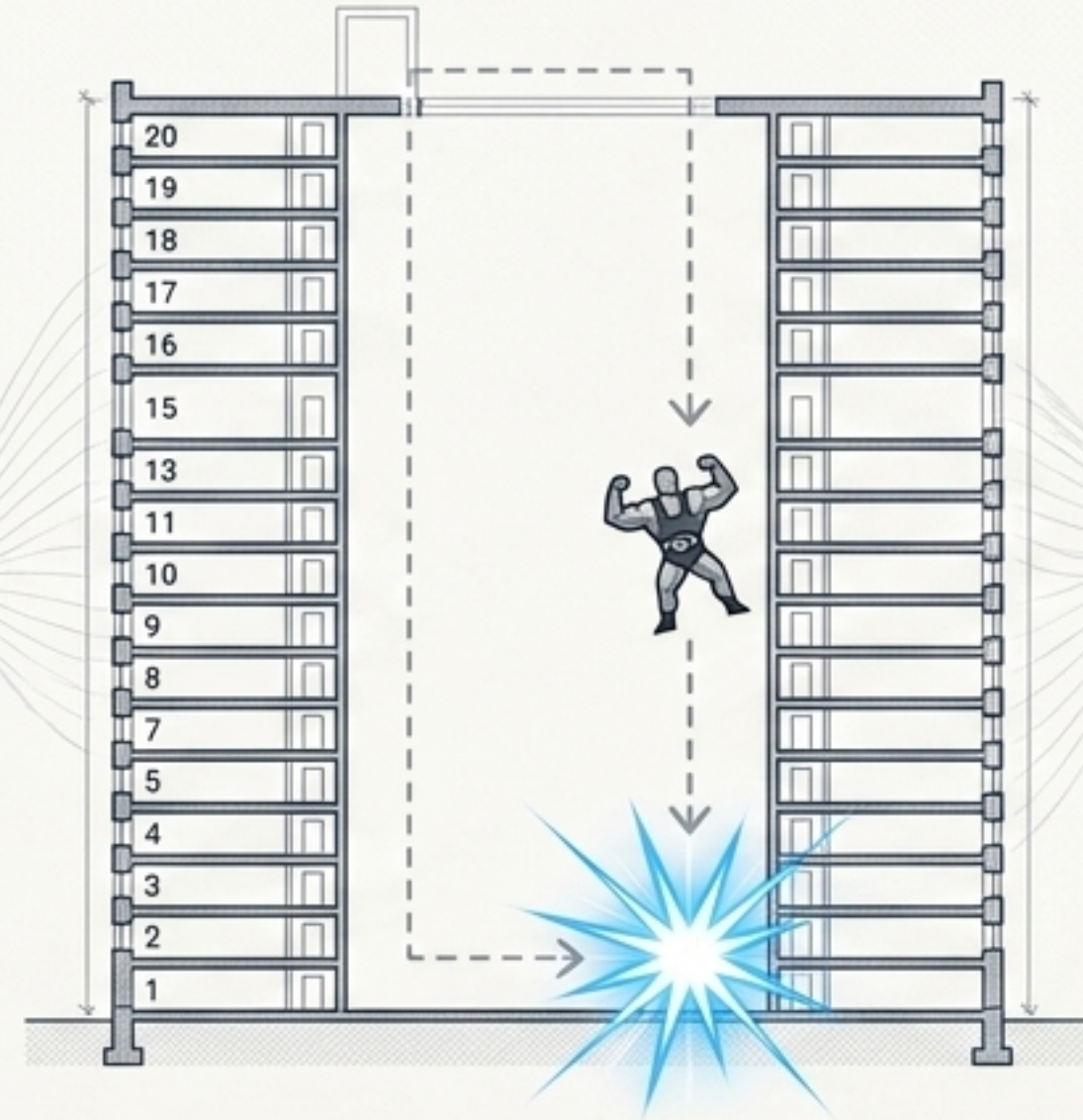
# The Strongman Analogy: Heat vs. Light

## Macro-Crystal



Macro-Crystal: In a large crystal, energy levels shatter into a continuous, dense staircase. An electron shuffles down slowly, turning energy into heat.  
(Take the stairs = just get a sweat).

## Nano-Crystal

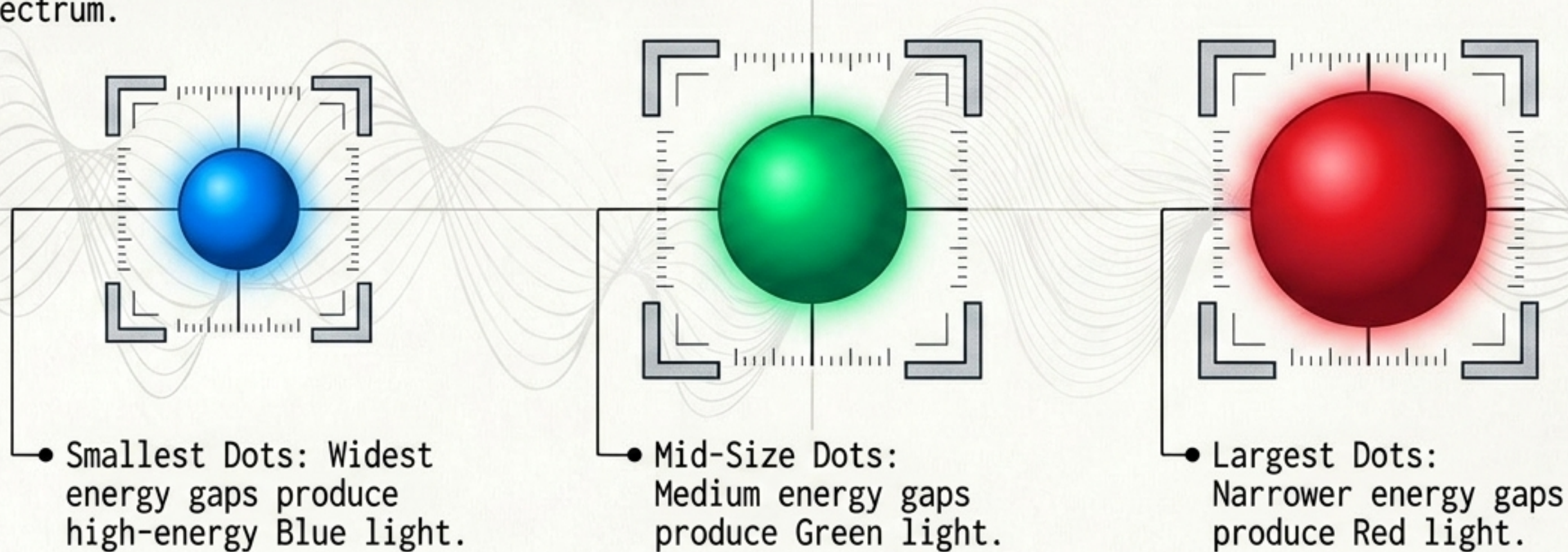


Nano-Crystal: Shrink the crystal to a few nanometers. Electrons are re-confined. The levels snap back to discrete, massive gaps. An electron falls in a single leap, flashing into light.  
(Drop off the roof = pure photon).



# Quantum Dots: Sizing the Spectrum

The 2023 Nobel Prize in Chemistry was awarded for this mastery of quantum confinement. By controlling the precise nanometer size of the crystal, engineers literally point at a color on the spectrum.

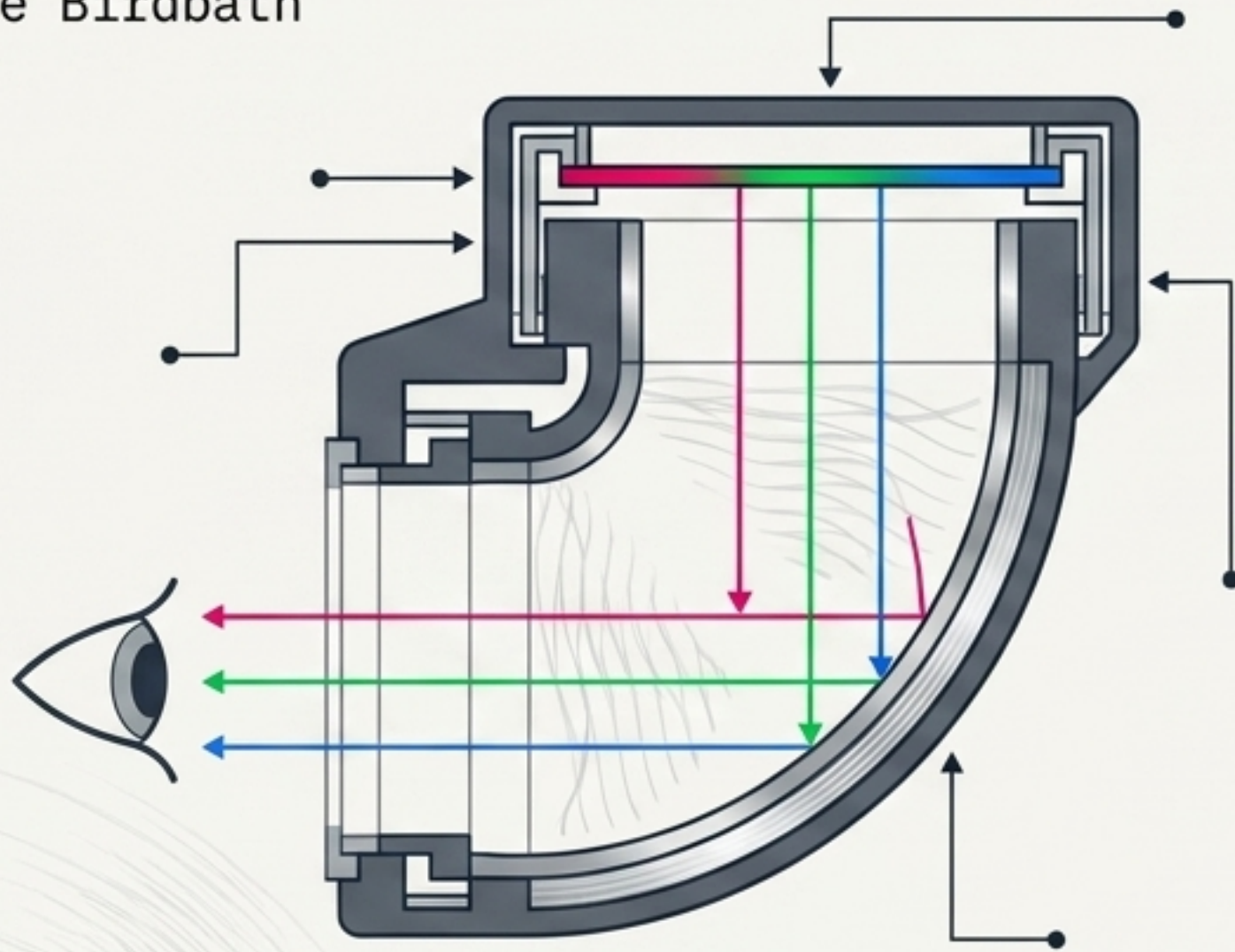


Footer Note: High-end LCDs hit these dots with blue light to yield perfectly pure RGB white backlights.



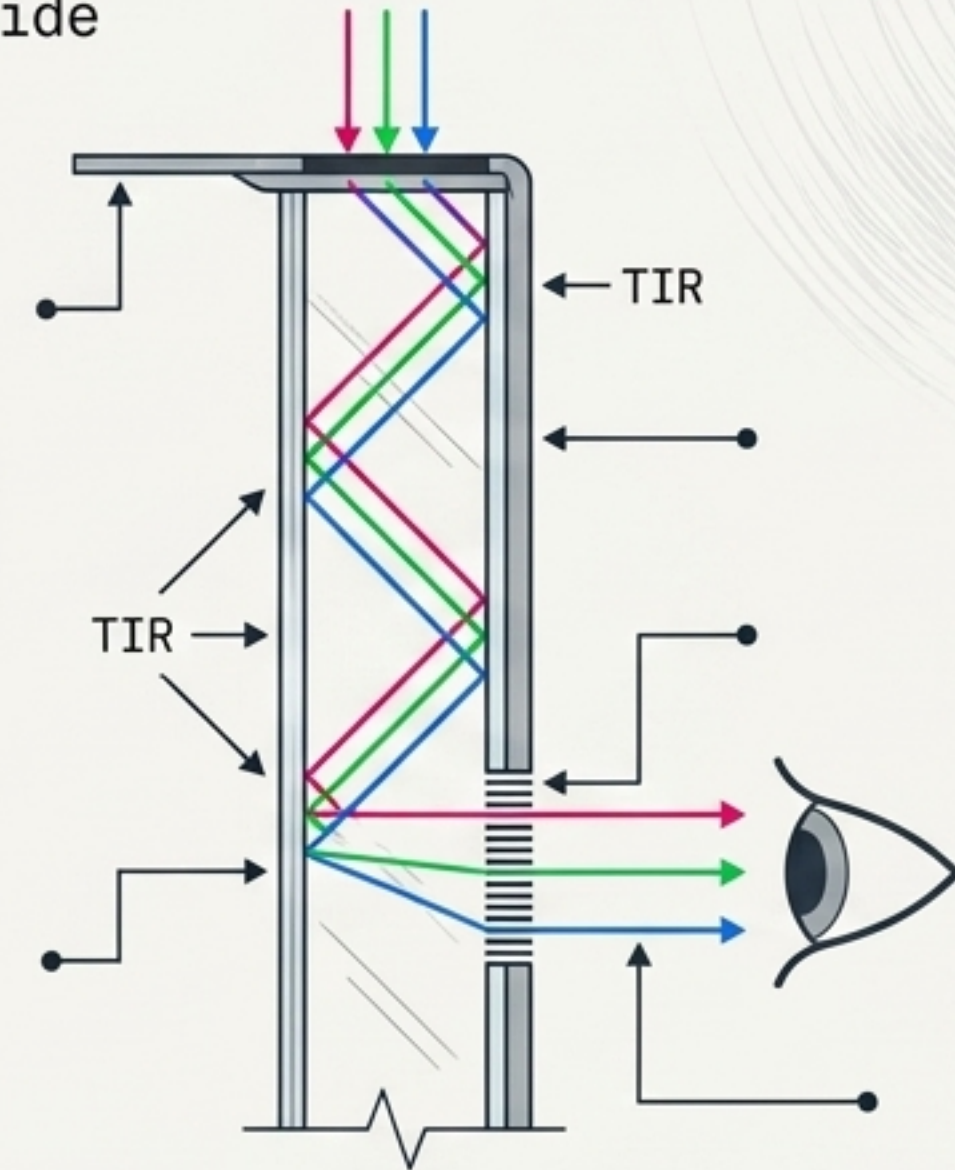
# Trapping Light in Glass: AR Architectures

The Birdbath



Birdbath: Uses a spherical half-mirror surface (shaped like a park birdbath) to fold the image. Bright, but thick and bulky. Unusable for everyday wear.

The Waveguide

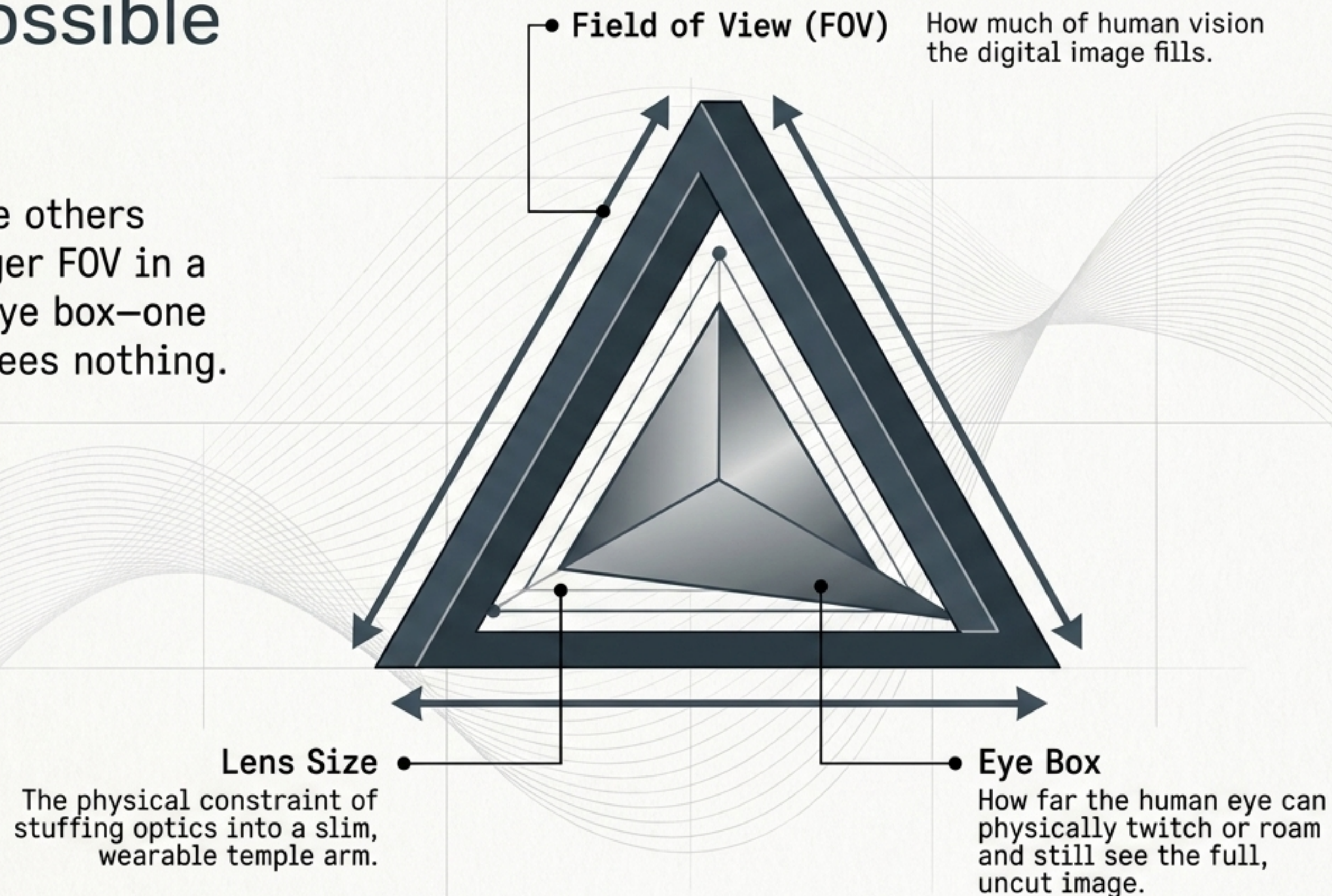


Waveguide: Tucks the screen into the temple arm. Uses total internal reflection to pipe light down the glass and release it into the eye through stacked half-mirrors (geometric) or gratings (diffractive). Slim and discreet.



# The AR Impossible Triangle

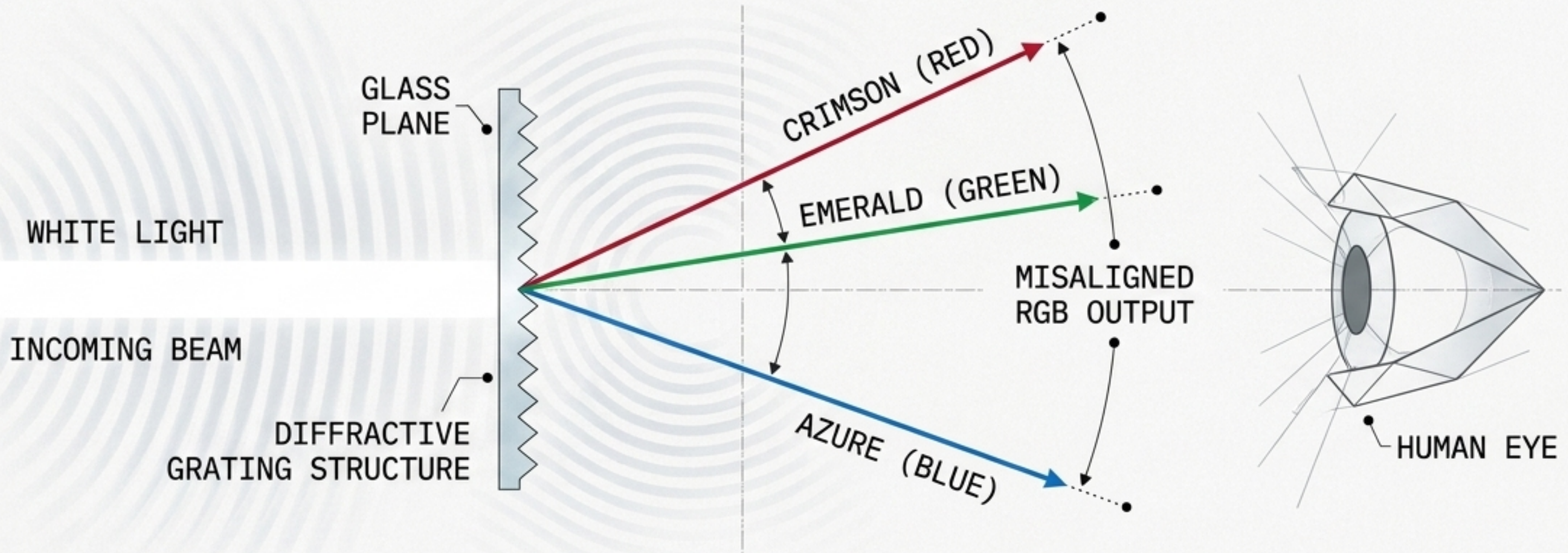
Push one limit, and the others inevitably give. A larger FOV in a small lens costs the eye box—one twitch, and the user sees nothing.





# The Diffraction Pitfall in AR

Diffraction returns to ruin the image. Different colors diffract at different angles. RGB light exits a diffractive waveguide entirely misaligned—rendering the image “beaten black and blue.”



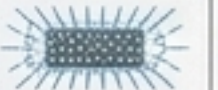
## The Engineering Band-Aids

### Monochrome Green



Many glasses default to single-color green, bypassing color alignment entirely (since the human eye is most sensitive to green).

### Micro-LED Brute Force



To achieve readable full color against daylight, AR requires brutally bright **Micro-LED screens** to muscle their light through the optical loss.



# The Arc of Control

From a glowing filament to a transistor steering electrons. From a 13.5nm laser embroidering circuits to quantum dots synthesizing perfect color.

ELECTRICITY

Nano-Optics Core

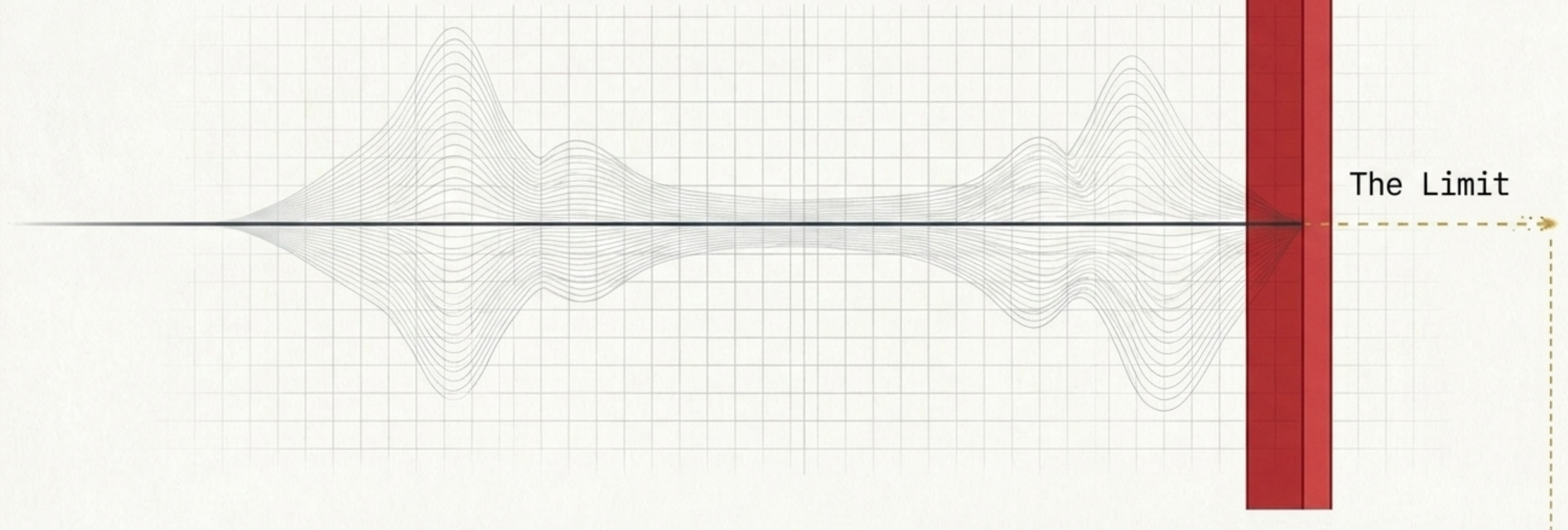
LIGHT

The entirety of modern computing is a single, continuous act: taking **electricity and light**—the universe's two most unruly forces—and pressing them, nanometer by nanometer, **into the palm of the hand**.



# The Final Inch

Some predict silicon-based scaling finally has a real ceiling.  
That below 6.7 nanometers, physics will simply refuse to yield.



But for a hundred years now, every time  
someone said 'this is the limit,' someone  
else insisted on pushing **one inch further**.