(Dated: January 17, 2026)

We model the photon as a one-dimensional, closed or open swirl string with phase $\phi(\mathbf{x}, t)$ propagating helically along the string. Spin (circular polarization) corresponds to the handedness of the local swirl clock; optical orbital angular momentum (OAM) with topological charge ℓ is the phase winding in the transverse plane. For laser beams we use the (paraxial) Gaussian beam and its Laguerre–Gaussian extension to plot intensity and phase fields. All formulas are SI-dimensional and calibrated to the SST scale $\Omega_0 = \|\mathbf{v}_{\circlearrowleft}\|/r_c$. In the *Rosetta* mapping, the scalar phase mode plays the role of a Maxwell-like radiation sector with $\omega = ck$ in uniform backgrounds, while OAM corresponds to azimuthal phase winding.

I. KINEMATICS: PHOTON AS A HELICAL MODE ON A SWIRL STRING

Let $\mathbf{X}(s, t)$ denote the string centerline with arclength parameter s and local tangent $\mathbf{t}$. A photon is modeled as a travelling phase wave on the string:

$$\phi(\mathbf{x}, t) = kz - \omega t + \ell\,\theta, \qquad k = \frac{2\pi}{\lambda}.$$

where $k = 2\pi/\lambda$, $\omega = 2\pi f$, and (r, θ, z) are cylindrical coordinates along the propagation axis. *Spin*/polarization is the local swirl-clock handedness (left/right), and *OAM* is the integer winding $\ell \in \mathbb{Z}$ around the beam axis [1, 2].

a. SST clock and energy density. A convenient reference scale is

$$\Omega_0 = \frac{\|\mathbf{v}_{\circlearrowleft}\|}{r_c} \quad [\mathrm{s}^{-1}].$$

Dimensional check: $[\mathbf{v}_{\circlearrowleft}] = \mathrm{m\,s^{-1}}$, $[r_c] = \mathrm{m}$, so Ω_0 is a frequency. Numerically this recovers the electron Compton scale in the canonical calibration and is used as a normalization point.

II. ENERGY, MOMENTUM, AND POLARIZATION

For a single photon, $E = \hbar\omega$ and $p = \hbar k$ (standard field theory). Within SST, the energy is associated with an effective string line energy. Without committing to microstructure, the operative identification is

$$\boxed{E = \hbar\omega, \quad \mathbf{p} = \hbar\mathbf{k}, \quad \text{spin } S = \pm\hbar \;\leftrightarrow\; \text{swirl-clock left/right}}$$

where $+$ and $-$ correspond to left- and right-circular polarization, respectively.

III. LASER-BEAM MODEL: GAUSSIAN BEAM AND LG MODES

For a paraxial beam with waist w_0 at $z = 0$ ([1]):

$$w(z) = w_0\sqrt{1 + (z/z_R)^2}, \qquad z_R = \frac{\pi w_0^2}{\lambda}, \tag{1}$$

$$R(z) = z\left[1 + \left(\frac{z_R}{z}\right)^2\right], \qquad \zeta(z) = \arctan\left(\frac{z}{z_R}\right). \tag{2}$$

The TEM_{00} scalar field amplitude is

$$E_{00}(r,z) = E_0 \frac{w_0}{w(z)} \exp\Big(-\frac{r^2}{w(z)^2}\Big) \exp\Big(ikz - i\omega t + i\frac{kr^2}{2R(z)} - i\,\zeta(z)\Big),$$

The intensity is $I = \frac{1}{2}\epsilon_0 c\,|E|^2$ (units $\mathrm{W\,m^{-2}}$). Laguerre–Gaussian (LG) with OAM ℓ and radial index p:

$$E_p^{\ell}(r,\theta,z) = E_{00}\left(\frac{\sqrt{2}\,r}{w(z)}\right)^{|\ell|} L_p^{|\ell|}\left(\frac{2r^2}{w(z)^2}\right) e^{i\ell\theta}.$$

For $\ell \neq 0$ there is an on-axis null; the ring maximum occurs at $r_{\max}(z) = w(z)\sqrt{|\ell|/2}$.

IV. NUMERICAL EXAMPLE AND FIGURES

Example parameters: $\lambda = 632.8\,\mathrm{nm}$, $w_0 = 1.0\,\mathrm{mm} \Rightarrow z_R = \pi w_0^2/\lambda = 4.9646\,\mathrm{m}$ and beam divergence $\theta_{\mathrm{div}} = \lambda/(\pi w_0) = 0.201\,\mathrm{mrad}$.

a. Reading guide. Fig. 1 shows the TEM_{00} intensity at the waist ($z = 0$). Fig. 2 shows the 2π phase winding for $\ell = 1$ (OAM, on-axis null). Fig. 3 confirms the known $w(z)$ scaling and the asymptotic divergence.

Known limits: $w(0) = w_0$, far-field $z \gg z_R$ gives opening angle $\theta_{\mathrm{div}} = \lambda/(\pi w_0)$, and for $\ell \neq 0$ there is an axis null with ring maximum $r_{\max}(z) = w(z)\sqrt{|\ell|/2}$ [2, 3].

V. PLOTTING RECIPE (ALGORITHM)

1. Choose λ, w_0; compute $z_R = \pi w_0^2/\lambda$.

2. Define a 2D grid in the $z = 0$ plane; compute $I(r,0) \propto e^{-2r^2/w_0^2}$ (TEM_{00}).

3. For OAM, take phase $\Phi = \ell\,\theta$ and (optionally) the LG envelope.

4. For a longitudinal cut: plot $w(z)$ and (optionally) $r_{\max}(z)$.

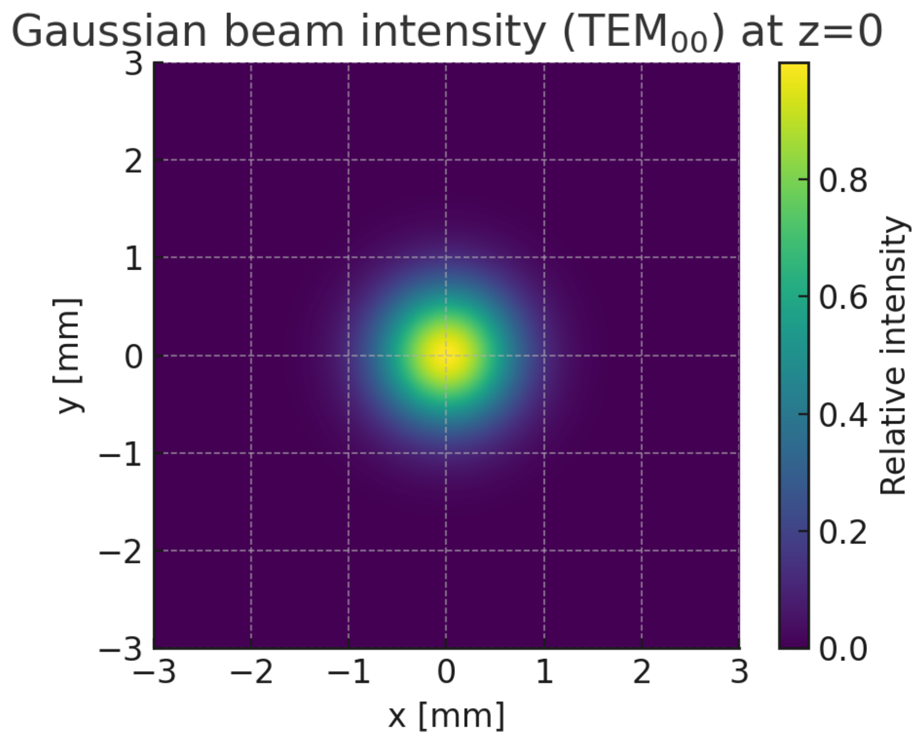

FIG. 1: Gaussian intensity (TEM_{00}) in the z=0 plane. The map shows $I(r,0) \propto \exp(-2r^2/w_0^2)$ with a central peak and radial Gaussian decay. With $\lambda = 632.8\,\mathrm{nm}$ and $w_0 = 1.0\,\mathrm{mm}$ this is the beam waist. The dimension of I is $\mathrm{W\,m^{-2}}$; relative scale shown.

VI. PREDICTIONS (FALSIFIABLE) AND EDGE CASES

P1 (spinswirl-clock). Polarization helicity coincides one-to-one with the handedness of the local swirl clock; spin–to–orbital conversion under strong focusing produces steps in ℓ (test via forked interferograms [3]). **P2 (OAM ring).** The on-axis null and ring radius $r_{\max}$ follow the LG scaling; deviations at extreme focusing (non-paraxial) predict measurable phase modulations. **Edge cases.** Non-paraxial ($w_0 \sim \lambda$), dispersive media, and the near field of structures (locally non-Gaussian) call for fully vectorial solutions.

VII. MAINSTREAM MAPPING (ROSETTA-STYLE QUICK DICTIONARY)

The following items summarize the translation to standard EM/QO language, consistent with Rosetta v0.6:

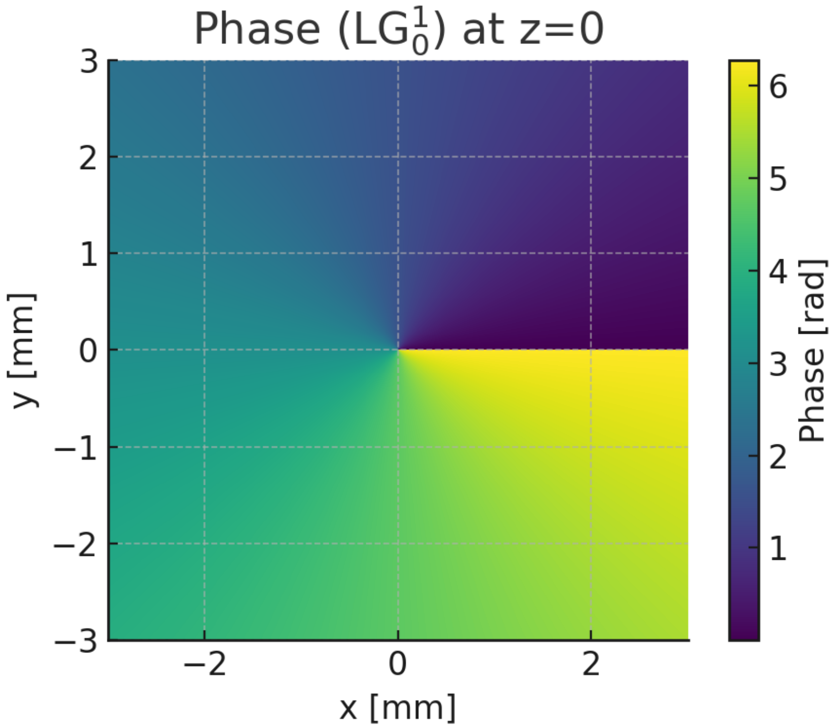

FIG. 2: Phase field for LG_0^1 with topological charge ℓ=1 at z=0. The phase $\Phi(\theta) = \ell\,\theta$ winds by 2π around the axis and has a singular core (dark "vortex"): zero intensity on-axis and a ring maximum at $r_{\max}(0) = w_0/\sqrt{2} = 0.707\,\mathrm{mm}$. This visualizes optical OAM.

- **Scalar radiation mode**: phase field obeys $\partial_t^2\theta - c^2\nabla^2\theta = 0$ in uniform regions (luminal calibration).
- **Polarization**: spin $\pm\hbar$ maps to left/right circular polarization (handed swirl-clock).
- **OAM**: integer ℓ equals azimuthal phase winding; LG modes are standard paraxial solutions.
- **Energy/momentum**: $E = \hbar\omega$, $p = \hbar k$; intensity $I \propto |E|^2$ as in optics.
- **Analogue metric**: weak-field lensing/time-delay effects track gradients of the swirl energy fraction (see Rosetta).

a. Kid analogy. A photon is like a tiny corkscrew ripple that travels along an invisible string: turning left or right sets polarization; adding an extra twist per loop yields OAM

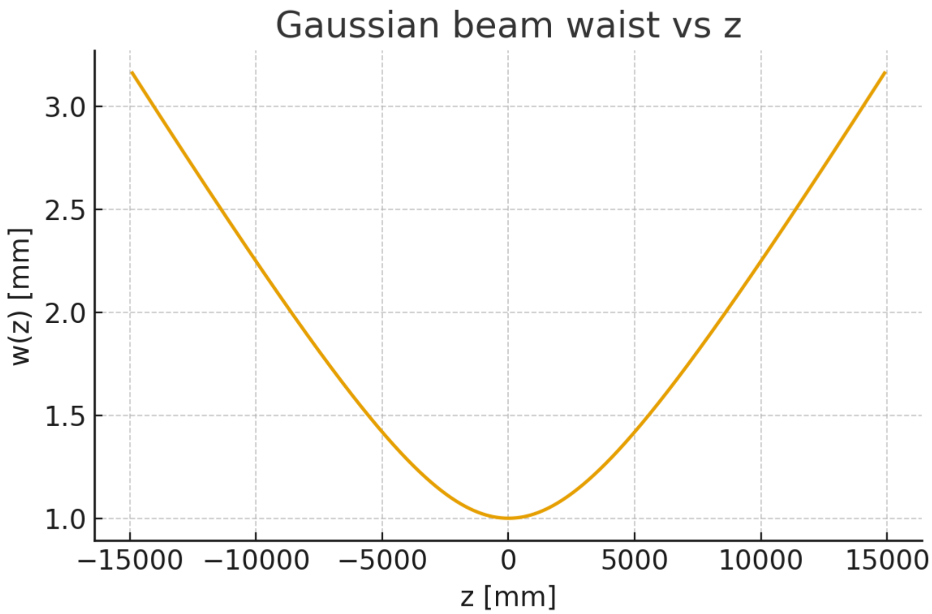

FIG. 3: Beam waist $w(z)$ versus z. For $|z| \ll z_R$ the beam remains narrow; for $|z| \gg z_R$ one has $w(z) \approx |z|\theta_{\rm div}$ with $\theta_{\rm div} = \lambda/(\pi w_0)$. The Rayleigh range $z_R = 4.9646\,\mathrm{m}$ marks the near- to far-field transition.

rings.

[1] A. E. Siegman, *Lasers*, University Science Books (1986).

[2] L. Allen *et al.*, Phys. Rev. A **45**, 8185 (1992).

[3] M. V. Berry, J. Opt. A **6**, 259 (2004).