Internal Memo: Mass from Light

Coherence Energy, the Eight-Tick Clock, and the Ladder Spectrum

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1 Executive Summary

Two distinct meanings of "mass from light." This memo uses the phrase *mass from light* in two layered senses:

- **Standard relativity (the "true derivation"):** light (photons) is individually massless, but *any isolated system of light* can have *nonzero invariant mass* whenever its total four-momentum is timelike. Equivalently, *confined radiation* contributes an inertial/gravitational mass increment $\Delta M = E_{\mathrm{rad}}/c^2$.
- **RS modeling statement (how RS uses the phrase):** RS organizes particle mc^2 values as a φ-ladder built on a coherence-energy unit E_{coh}. In that sense, the mass spectrum is "made of" a light-linked energy quantum times discrete rungs.

Refereeing note (what was wrong before, and what is fixed here). The earlier draft of this memo correctly stated the RS mass-law formula but (i) pointed to a non-existent file name (`Source-Super-rrf.txt`), (ii) used stale repo paths (`reality/IndisputableMonolith/...`), and (iii) implicitly mixed the IR-gate identity with a Planck-gate display formula. This revision corrects those pointers, separates the layers explicitly, and adds the standard SR/GR derivation of how light energy yields invariant mass.

2 Repository Ground Truth (Definitions vs. Bridge Displays)

Golden ratio. φ denotes the golden ratio

$$\varphi := (1 + \sqrt{5})/2.$$

In Lean this is `IndisputableMonolith.Constants.phi` (in `IndisputableMonolith/Constants.lean`).

Coherence factor in the model layer (dimensionless). In the Lean *model layer*, the coherence quantity is defined as a *dimensionless* factor

$$\epsilon_{\mathrm{coh}} := \varphi^{-5}.$$

This is `Anchor.E_coh` in `IndisputableMonolith/Masses/Anchor.lean`. When papers/memos quote "$E_{\text{coh}} \approx 0.09017\,\text{eV}$", they are using the display convention $E_{\text{coh}} := \epsilon_{\text{coh}}\,\text{eV}$ (a choice of units, not a Lean theorem).

Display numerics (IR scale). Under the common convention $E_{\text{coh}} := \epsilon_{\text{coh}}\,\text{eV}$, one has $E_{\text{coh}} \approx 0.09017\,\text{eV}$, corresponding to an infrared photon scale $\lambda \approx 13.8\,\mu\text{m}$ (equivalently $\tilde{\nu} \approx 724\,\text{cm}^{-1}$). This IR-scale interpretation appears explicitly in the super-source (see `book/papers/txt/Source-Super.txt`, e.g. the "eight_beat_IR" notes).

Eight-tick minimality (proved witness). The eight-tick claim exists in Lean as a witness proposition `RH.RS.eightTickWitness` and is proven via `Patterns.period_exactly_8`; see `IndisputableMonolith/RH/RS/Spec.lean`. A corresponding certificate wrapper exists as `URCGenerators.EightTickMinimalCert` in `IndisputableMonolith/URCGenerators/CoreCerts.lean`.

IR gate (stated in the super-source). The project super-source records an IR gate identity

$$\hbar = E_{\text{coh}}\,\tau_0 \quad \text{(IR gate statement)}.$$

See `book/papers/txt/Source-Super.txt` (entry `IR_GATE`, field `hbar_identity`). *Referee clarification:* this identity is **dimensionally meaningful only after you specify what physical units E_{coh} carries**. In the Lean model layer ϵ_{coh} is dimensionless; converting it into Joules/eV is part of the bridge-to-SI story.

2π bookkeeping (avoiding a common confusion). Recall $E = \hbar\omega$ and $T = 2\pi/\omega$, hence $E = 2\pi\hbar/T$. Thus an identity of the form $\hbar = E\,\tau$ naturally corresponds to $\tau = 1/\omega$ (a time-per-radian), whereas formulas written with $2\pi\hbar/\tau$ treat τ as a cycle period.

Planck-gate display (Lean bridge helper). Separately, the Lean *bridge display* includes a Planck-side construction

$$\lambda_{\text{rec}}(B) := \sqrt{\frac{\hbar G}{\pi c^3}}, \qquad \tau_{\text{rec}}(B) := \frac{\lambda_{\text{rec}}(B)}{c},$$

and then defines an *energy-scale display*

$$E_{\text{coh}}^{\text{disp}}(B) := \varphi^{-5}\,\frac{2\pi\hbar}{\tau_{\text{rec}}(B)}.$$

This is implemented as `IndisputableMonolith.Bridge.DataExt.tick_tau0` and `IndisputableMonolith.Bridge.DataExt.E_coh` in `IndisputableMonolith/Bridge/DataExt.lean`. *Referee note:* this is a Planck-gate display expression (it uses $G, \hbar, c$); it should not be silently identified with the IR-gate statement without an explicit "no-mixing" justification.

3 The True Derivation: How Light Contributes to Mass

3.1 Invariant mass from four-momentum (SR)

Definition. For any isolated system in special relativity, define total energy E and total momentum $\mathbf{p}$ in a given inertial frame. The invariant mass M of the *whole system* is

$$M^2c^4 = E^2 - (pc)^2, \qquad p := \|\mathbf{p}\|. \tag{1}$$

Equivalently, if $P^\mu = (E/c, \mathbf{p})$, then $M^2c^2 = P^\mu P_\mu$.

Key point. A single photon satisfies $E = pc$, so (1) gives $M = 0$. But a *collection* of photons can have $M > 0$ whenever the vector momenta fail to sum to a null total.

3.2 Two-photon example (why "light can make mass" without contradiction)

Take two photons each of energy E_γ with an angle θ between their momentum vectors. Then $E_{\text{tot}} = 2E_\gamma$ and $p_{\text{tot}} = \|\mathbf{p}_1 + \mathbf{p}_2\| = 2(E_\gamma/c)\cos(\theta/2)$. Plugging into (1):

$$M^2c^4 = (2E_\gamma)^2 - \big(2E_\gamma\cos(\theta/2)\big)^2 = 4E_\gamma^2\sin^2(\theta/2),$$

so

$$M = \frac{2E_\gamma}{c^2}\,\sin(\theta/2). \tag{2}$$

Special cases: $\theta = 0 \Rightarrow M = 0$ (collinear photons behave like one photon); $\theta = \pi \Rightarrow M = 2E_\gamma/c^2$ (head-on pair has a rest frame).

3.3 "Box of light" (confined radiation has inertia)

Consider a perfectly reflecting cavity that contains radiation of total energy E_{rad} in the cavity rest frame. By symmetry the total momentum vanishes in that rest frame, so (1) gives a system mass increment

$$\Delta M = \frac{E_{\text{rad}}}{c^2}. \tag{3}$$

This is the cleanest statement of "mass from light" in standard physics: *energy stored as radiation contributes to the rest mass of the composite system.*

Why confinement matters. If the light is not confined, there is generally no rest frame (the total four-momentum can be null). Confinement (or any arrangement that yields a timelike total four-momentum) is what turns massless quanta into a massive composite.

3.4 Einstein's two-pulse argument (why $E = mc^2$ follows from SR + conservation)

Consider a body of rest mass M that, in its rest frame, emits two photons of equal energy $L/2$ in opposite directions. In that rest frame the net momentum of the light is zero, so the body does not recoil; its rest mass changes to M'.

Now view the same emission in a frame where the body moves at speed v along the emission axis, with $\beta := v/c$ and $\gamma := 1/\sqrt{1-\beta^2}$. Photon energies transform as $E' = \gamma E(1 \pm \beta)$, so the forward/back photon energies are

$$E'_\pm = \gamma\,\frac{L}{2}\,(1 \pm \beta),$$

hence the light carries net momentum

$$p'_{\text{light}} = \frac{E'_+ - E'_-}{c} = \gamma\,\frac{L\beta}{c}.$$

Since the body does not recoil in its rest frame, it continues at the same speed v in this moving frame; its momentum therefore changes only because its mass changed:

$$\gamma M v - \gamma M' v = p'_{\text{light}}.$$

Canceling γv gives

$$(M - M')c^2 = L.$$

Thus emitting (or absorbing) light energy L changes inertial mass by L/c^2. This is the classic "mass from light" derivation.

3.5 GR viewpoint (stress–energy, pressure, and the "Tolman paradox")

General relativity replaces "mass sources gravity" with "stress–energy sources curvature." Radiation has pressure as well as energy density, so naively it can look like "pressure gravitates too." For a *closed, static* system (radiation + container + stresses), those stress contributions are not optional: the wall stresses required to confine radiation contribute with opposite sign in the relevant global mass formula, and the net gravitational mass reduces to the same total-energy statement (3). Operationally: a cavity full of light weighs more by $E_{\rm rad}/c^2$.

Connection back to RS language. Equations (3) and $(M - M')c^2 = L$ are the mainstream content behind the slogan "mass from light":
emphstable, bound field energy contributes to rest mass. RS's additional claim is not this equivalence, but the specific discrete φ-ladder organization of the stabilized (coherent) energy spectrum.

4 How RS Uses "Mass from Light" (Ladder Spectrum)

Mass in energy units. In RS mass formulas, "mass" is often treated in particle-physics units where one quotes mc^2 in eV/GeV. With that convention, the phrase "mass from light" becomes literal: the mass scale is built from a light-linked energy unit.

Canonical spectrum statement (super-source). The project super-source summarizes the mass spectrum as

$$m_{\mathrm{pole},i} = B_i \, E_{\rm coh} \, \varphi^{\, r_i + f^{\rm Rec}(Z_i) + f_i^{\rm RG}}, \qquad r_i \in \mathbb{Z}, \quad B_i \in \{2^k : k \in \mathbb{Z}\}. \tag{4}$$

See `book/papers/txt/Source-Super.txt` (block `@SPECTRA` $\to$ `MASS_LAW`).

4.1 The three ingredients

(1) Sector prefactor B_i. B_i is a sector-global power-of-two prefactor (leptons vs up-quarks vs down-quarks vs EW), implemented in Lean as `Anchor.B_pow` in `IndisputableMonolith/Masses/Anchor.lean`.

(2) Rung integer r_i. r_i is an integer rung. Example rung tables are implemented in Lean as `Integers.r_lepton`, `Integers.r_up`, `Integers.r_down`, `Integers.r_boson` in `IndisputableMonolith/Masses/A`

(3) Recognition residue $f^{\rm Rec}(Z)$ and RG residue $f_i^{\rm RG}$. In the mass manuscripts, the spectrum separates a closed-form recognition-side residue from a small Standard-Model transport correction. A canonical closed form used across the repo is

$$f^{\rm Rec}(Z) = \frac{1}{\ln \varphi} \ln\!\Big(1 + \frac{Z}{\varphi}\Big), \tag{5}$$

with an RG transport term $f_i^{\rm RG}$ used only for like-for-like comparison across schemes/scales. (See `Papers-tex/Masses-Paper1-Single-Anchor-updated.txt` for the framework-separated statement.)

4.2 The integer charge map Z

RS encodes a charge-derived integer Z (“word charge”) using the scaled charge $\tilde{Q} := 6Q \in \mathbb{Z}$:

$$Z = \begin{cases} \tilde{Q}^2 + \tilde{Q}^4, & \text{charged leptons,} \\ 4 + \tilde{Q}^2 + \tilde{Q}^4, & \text{quarks,} \\ 0, & \text{Dirac neutrinos (in the stated model).} \end{cases}$$

This is implemented as `ChargeIndex.Z` in `IndisputableMonolith/Masses/Anchor.lean`.

5 Single-Anchor Evaluation Point ($\mu_\star$)

For Standard-Model running-mass residues, the project uses a common anchor scale

$$\mu_\star = 182.201 \text{ GeV}, \qquad \lambda = \ln \varphi, \qquad \kappa = \varphi,$$

as recorded in `book/papers/txt/Source-Super.txt` (block `@SM_MASSES`).

6 Where This Lives in the Repo (Pointers)

- **Mass constants and integer maps (Lean, model layer):** `IndisputableMonolith/Masses/Anchor.lean`.
- **Eight-tick witness and certificates (Lean):** `IndisputableMonolith/RH/RS/Spec.lean` and `IndisputableMonolith/URCGenerators/CoreCerts.lean`.
- **Bridge display helpers (Lean):** `IndisputableMonolith/Bridge/Data.lean` and `IndisputableMonolith`
- **Single-anchor mass manuscript (framework-separated):** `Papers-tex/Masses-Paper1-Single-Anchor`
- **One-file narrative summary (mass law, IR gate, SM anchor):** `book/papers/txt/Source-Super.txt`.