Phase Geometry Series — Overview

Coherence, Electromagnetism and Weak Gravity in a Phase-Based Framework

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1 Series map: six notes, one theme

The Phase Geometry Series explores how a single macroscopic phase field can organise familiar physics across superconductivity, electromagnetism and weak gravitation. The intent is modest: to provide a phase-based language and a few simple models that sit on top of standard theory (BCS, Maxwell, GR), not to replace it.

The series currently consists of six tightly connected notes, grouped in two layers:

Resonance layer (operational device language):

Resonance Intro — Operational Phase Framework for Devices

Dimension: standard $3 + 1$ SC/EM physics (no explicit Z_2 or 5D).
Role: conceptual overview of the Resonance programme.

This short note explains why the Resonance framework is introduced as an intermediate "operational" layer. Superconducting and quantum devices are described in terms of phase fields, *phase rotators*, *phase meters* and *resonant field cells*, with a single key figure of merit: the phase–flux coupling coefficient $\alpha(d, \omega)$. The note emphasises five advantages of this language: (i) unification and compression of device descriptions, (ii) a clear figure of merit via $\alpha(d, \omega)$, (iii) a clean interface to the Z_2 and Phase-Fibre (5D) branches, (iv) direct experimental testability via thick SNS phase-rotator devices, and (v) a conceptual shift beyond "SQUID-only" phase control.

Resonance Device Note — Phase-Device Zoo

Dimension: 3D devices (superconducting, normal-state, mesoscopic).
Role: taxonomic device dictionary in the Resonance language.

This note collects a set of standard quantum and semiclassical devices — Josephson junctions, SQUIDs, thick SNS weak links, Esaki and resonant-tunnelling diodes, Gunn and IMPATT devices, Aharonov–Bohm rings, quantum point contacts, single-electron transistors, quantum cascade lasers — and repackages them as phase rotators, phase meters and phase-engineered media. The focus is deliberately conceptual: each device is assigned a natural phase object, a qualitative role (rotator / meter / medium) and, where appropriate, the presence of negative differential resistance. This "phase-device zoo" serves as a shared device-level interface for the Z_2 and Phase-Fibre branches.

Part I — Resonant Field Symmetry in Superconductors

Dimension: 3D physical systems (superconducting samples and junctions).
Role: phenomenological prologue / intuition.

Part I introduces the idea of *resonant field symmetry*: superconductors are treated as phase-coherent media in which electromagnetic fields form standing patterns. Meissner screening, surface currents and Josephson barriers are re-organised into a geometric language of phase fields, *phase rotators* (weak links where the phase flow is turned) and *Resonant Field Cells*, localized regions where phase and fields form a standing mode.

Part I-B — Resonant Field Framework and Classical Basis

Dimension: 3D devices + classical field theory.
Role: calculational backbone and device dictionary for Part I.

Part I-B develops a two-layer description of magnetic phase control in superconducting weak links. On the *effective* level, it formulates a Resonant Field (RF) framework with phase rotators, RF Cells, a Phase–Control Equation and a key phase–flux coefficient $\alpha(d, \omega)$. On the *classical* level, it shows how the same objects arise from Ginzburg–Landau / Usadel theory, London–Maxwell electrodynamics and the RCSJ model.

Thick SNS weak links with local microcoils are used as a concrete platform, and realistic conditions for a strong-rotator regime $|\alpha| \sim 0.3$–0.6 are identified.

Phase-fibre and gravity layer:

Part II — Phase-Coherent Josephson Devices as Clocks in Weak Gravitational Fields

Dimension: 5D phase-fibre geometry (4D spacetime + compact U(1) phase).
Role: geometric core.

Part II introduces a minimal *phase-fibre Kaluza–Klein metric* in which a compact U(1) fibre with coordinate ϕ is attached to spacetime, and the electromagnetic potential appears as the corresponding connection. A macroscopic superconducting condensate is described as a section of this bundle, so that Josephson phases become explicit geometric variables.

In a static weak gravitational field the condensate phase acts as an internal clock with a universal phase-rate law

$$\frac{d\phi}{dt} = \omega_0 \sqrt{-g_{00}(x)} \simeq \omega_0 \left(1 + \frac{\Phi(x)}{c^2}\right), \tag{1}$$

reproducing the familiar gravitational redshift for any phase-based clock. Applied to Josephson junctions and SQUID interferometers, this yields the expected redshift of ac-Josephson frequencies and rotation-induced (Sagnac-like) phase shifts, with order-of-magnitude estimates for realistic devices.

Part III — Phase-Field Newtonian Gravity and Phase Clocks

Dimension: 3D effective phase field (static, non-relativistic).
Role: calculable application / analogue gravity model.

Part III constructs a simple *phase-field model of Newtonian gravity.* A real static phase field $\phi(\mathbf{x})$ carries gradient energy, which is taken to define an effective mass density

$$\rho_{\text{eff}}(\mathbf{x}) = \frac{\kappa}{c^2} \, |\nabla\phi(\mathbf{x})|^2 \,, \tag{2}$$

where κ is a phenomenological phase–gravity coupling constant. The Newtonian potential $\Phi(\mathbf{x})$ obeys the standard Poisson equation

$$\nabla^2\Phi(\mathbf{x}) = 4\pi G\,\rho_{\text{eff}}(\mathbf{x}), \tag{3}$$

so that localized phase defects behave as effective gravitating masses with a $1/r$ far-field potential.

Test particles follow ordinary Newtonian trajectories in Φ, and *phase clocks* (including Josephson clocks from Part II) experience the usual weak-field redshift encoded in $g_{00}(\mathbf{x})$. This provides a transparent "Newtonian floor" for phase geometry: standard Newtonian dynamics and weak time dilation expressed entirely in terms of a static phase texture.

Together, these six components — Resonance overview (Resonance Intro), the phase-device zoo, phenomenology (I), classical backbone (I-B), phase-fibre geometry (II) and phase-field gravity (III) — form a conceptual path from superconducting coherence to weak-field gravitation.

2 Geometric bridge: from phase rate to effective curvature source

The central geometric ingredient of Part II is the phase-fibre metric

$$ds^2 = g_{\mu\nu}(x)\,dx^\mu dx^\nu + R^2\left(d\phi + kA_\mu(x)\,dx^\mu\right)^2, \tag{4}$$

where a compact U(1) fibre with coordinate ϕ is attached to each spacetime point and A_μ acts as the corresponding connection. For a stationary coherent state, the phase-rotation rate with respect to coordinate time t obeys

$$\frac{d\phi}{dt} = \omega_0\sqrt{-g_{00}(x)}, \tag{5}$$

so that in the weak-field limit $g_{00} \simeq -(1 + 2\Phi/c^2)$ one has

$$\frac{d\phi}{dt} \simeq \omega_0\left(1 + \frac{\Phi(x)}{c^2}\right). \tag{6}$$

This is just the familiar gravitational redshift, expressed as a position-dependent rotation rate of a phase-based clock.

Part III starts from a purely spatial phase field $\phi(\mathbf{x})$ and postulates that the Newtonian potential $\Phi(\mathbf{x})$ is sourced by the phase-gradient energy density:

$$\rho_{\text{eff}}(\mathbf{x}) = \frac{\kappa}{c^2}\,|\nabla\phi(\mathbf{x})|^2, \qquad \nabla^2\Phi(\mathbf{x}) = 4\pi G\,\rho_{\text{eff}}(\mathbf{x}). \tag{7}$$

The coupling constant κ is phenomenological and *distinct* from the dimensionless phase–flux coefficient $\alpha(d,\omega)$ introduced in Parts I and I-B for superconducting phase rotators. The phase-field model is explicitly static, non-relativistic and confined to the weak-field regime, but it yields a well-defined effective mass density, Newtonian potential and clock redshift for any chosen phase texture.

The bridge between Parts II and III is therefore conceptual rather than a strict derivation:

- In Part II, phase rotation along the internal fibre is tied directly to g_{00} and hence to the gravitational potential Φ via the phase-rate law.
- In Part III, one takes seriously the idea that spatial variations of a phase carry energy, and uses a Poisson equation to define a Newtonian potential sourced by this energy density.

In static weak-field situations, both viewpoints are compatible: the same potential $\Phi(\mathbf{x})$ that appears in g_{00} in Part II can be regarded, at an effective level, as being generated by the phase-gradient energy that shapes $\phi(\mathbf{x})$ in Part III. This justifies treating coherent phase fields as analogue sources of weak curvature without modifying general relativity.

3 Scientific context and status

The Phase Geometry Series is not proposed as a replacement for the Standard Model or general relativity. Its status can be summarised as follows.

Interpretive framework

Resonance Intro, together with Parts I and II, provides a phase-based language that repackages well-established physics — London and Josephson relations, Maxwell electrodynamics, weak-field GR redshift — in terms of macroscopic phase, phase rotators and internal fibre geometry.

Phenomenological models

Part I-B offers a concrete RF framework for thick SNS weak links, with a clear dictionary to classical GL/Usadel + London–Maxwell + RCSJ theory and a practical figure of merit $\alpha(d, \omega)$ for device design. The Phase-Device Zoo extends this picture to a broader set of superconducting, normal-state and mesoscopic devices. Part III supplies a deliberately modest phase-field model for analogue Newtonian gravity in static weak regimes.

Connection to experiment

Part I-B emphasises localized magnetic phase control and coil-driven Shapiro steps as direct probes of $\alpha(d, \omega)$. The Resonance Device Zoo points to additional platforms (tunnelling diodes, interferometers, quantum point contacts, single-electron devices) where phase-based control and measurement can be formulated in the same language. Part II shows how Josephson devices and SQUIDs act as sensitive clocks and interferometers for weak gravitational and rotational fields. Part III points toward phase-engineered analogue-gravity scenarios in superconductors and other phase-ordered media.

Bridge between communities

Starting from superconducting devices (Resonance Intro, Part I, I-B), passing through a minimal phase-fibre parametrisation (Part II), and arriving at a simple phase-field Poisson model (Part III), the series is meant to build conceptual bridges between condensed-matter coherence, gauge geometry and weak-field gravity.

4 Outlook

Natural directions for future work include:

- extending the phase-fibre picture beyond the weak-field limit while remaining compatible with GR;
- exploring dynamical or spatially varying fibre radius $R(x)$ and its impact on phase clocks;
- connecting the phase-field gravity model to specific condensed-matter systems where phase textures can be engineered and imaged;
- using the phase-field Poisson model as a playground for analogue-gravity simulations and educational visualisations;

- developing semi-technical mappings in the Resonance Device Zoo, where effective phase variables and $\alpha_N(d, V, \omega)$ are derived explicitly from tunnelling and interference models (Esaki, RTD, Aharonov–Bohm rings, QPCs).

The guiding principle remains the same: coherence and phase are treated as geometric resources. The Phase Geometry Series invites the reader to view superconductors, electromagnetic fields and weak gravitational effects as different manifestations of a common *phase geometry*, while remaining firmly within the bounds of established theory.