

Measure the push of light.

A reviewed optical benchmark, conditional Alpha 1 formulation and reproducible uncertainty study.

The decision

Prioritize a conventional photon-force benchmark. Characterize graphene optical switching and heat before force integration. Hold Alpha 1 new-field hardware until a microscopic coupling mechanism and a mapped allowed parameter region survive qualified review.

Track	Current evidence	Next gate
MF-01 optical	Equations and planning calculations	Qualify reference force and disturbances
Graphene hybrid	Independent published optical result	Measure complete optical and thermal budget
A1-Y field	Conditional phenomenological model	Specify coupling; reproduce constraints

What this release is

A correction and extension of v0.1 following a supplied technical audit. Its recommendations were checked against primary publications and recalculated. Audit errors are identified rather than silently adopted. No device, staff appointment, measured thrust or independent peer review is claimed.

Accountability

Christopher Hill: founder and program sponsor. Experimental principal investigator, force-metrology lead and independent reviewer: not appointed. AI-assisted research, software and writing; specialist review remains pending.

The downloadable package includes model code, JSON/CSV outputs, original figures, protocol draft, source access notes and local citation metadata. No DOI or protocol registration has been deposited.

The field remains conditional.

An explicit normalization is useful only when its physical coupling can be specified.

Phenomenological equation

$$\nabla^2 \varphi - c^{-2} \partial^2 \varphi / \partial t^2 - \lambda^{-2} \varphi = 4\pi G \rho q$$

$$A_1 = -\nabla \varphi; F_t = -m q_t \nabla \varphi$$

φ has units m^2/s^2 , A_1 has units m/s^2 , λ is range, ρ is mass density and q is a dimensionless effective coupling. Write $q_t = q_0 + s q_1$, with $s = \pm 1$. The state-modulated product $b = q_s q_1$ is unknown. This is a proposed operationalization, not a derived or validated NetPhysics law.

Finite-source force kernel

$$K(r) = GMm f(R_s/\lambda) f(R_t/\lambda) \exp(-r/\lambda)(1+r/\lambda)/r^2$$

$$f(x) = 3[x \cosh(x) - \sinh(x)]/x^3; \text{ amplitude } F = bK.$$

Center separation	Newtonian force	Force per unit b
0.20 m	1.6686 nN	0.6952 nN
0.30 m	0.7416 nN	0.1516 nN
0.40 m	0.4171 nN	0.03920 nN

Assumptions: homogeneous 10 kg source and 0.1 kg target, density 19,300 kg/m³, $\lambda = 0.10$ m. Radii are 0.049825 m and 0.010735 m; spheres do not overlap. Unit b is a normalization, not an allowed or measured value.

The wider system

The quasistatic source and target exchange opposite forces. Co-mounting them makes that interaction internal. Time-dependent coupling additionally requires an actuator-energy model, field momentum and any radiated flux. The scalar equation alone does not supply that missing engineering or predict isolated self-acceleration.

Face existing constraints.

A unit-coupling curve is not a viable hardware specification.

A quantitative historical comparison

Murata and Tanaka (2015), summarizing Hoskins et al. (1985), report a conventional Yukawa α limit of order 10^{-3} at $\lambda = 0.10$ m [2]. If the same coupling applies to our geometry, that corresponds to about 0.695 pN at $r = 0.20$ m.

The v0.1 planning covariance assumed 0.8 nN noise per independent window, 128 windows per separation and a 0.05 nN common systematic standard uncertainty across three separations. It yields a 95% coupling half-width of 0.234, or 0.163 nN at 0.20 m: roughly 234 times the historical comparison force. These were simulated sensitivity assumptions, never qualified apparatus performance.

Why this is conditional

The conventional universal α and the state-changing product b are not interchangeable. Composition, screening, geometry, range and material-state populations must be mapped. A state-independent universal interaction may cancel in the source/state double-odd observable. The historical example is not the latest best constraint or a reanalysis of the original likelihood.

Equivalence-principle η is a separate observable. Ross et al. compare superconducting niobium and copper; their reported bound and Cooper-pair interpretation cannot be applied directly to an unspecified graphene gate [3]. An undefined coupling is a missing theory, not a loophole.

Stop / advance criteria

Stop a specified version if valid constraint mapping excludes its required parameter region, or if a qualified test excludes its frozen prediction. Hold when the microscopic mechanism, energy accounting or uncertainty is unresolved. Advance only with a surviving, detectable prediction and independent technical review. A model allowing arbitrarily zero coupling cannot be ruled out by a single null experiment.

Equilibrium nonreciprocity also supplies no general escape: the analyzed equilibrium Casimir forces derive from a free energy [4]. Driven systems must specify thermal reservoirs and momentum exchange.

Graphene: count every order.

The published operating point is an optical result, not a thrust measurement.

State	Selected angle	Absolute / relative efficiency
A · 10 V	−12°	7.8% / 83.6%
B · −80 V	+45°	8.4% / 76.5%

Han et al. use 45° incidence at 41.17 THz (7.281 μm). Their Methods report 3.37 mW and a 213 μm beam spot [1]. The final paper uses the term relative efficiency; the audit's terminology objection was not adopted.

Partial selected-order contribution

At fixed incident power and alignment, incoming lateral momentum cancels in B − A:

$$\Delta F_{x,\text{selected}} = -P[0.084 \sin(45^\circ) - 0.078 \sin(-12^\circ)]/c.$$

−2.522 nN at an illustrative 10 W; −0.850 pN at 3.37 mW. The audit's approximate 2.4 nN estimate was recalculated. These are our derived optical contributions, not reported forces.

Why the other order changes the answer

If the published rounded relative efficiencies account for all scattered power and only the two propagating orders contribute, the other-order fractions are $0.078/0.836 - 0.078$ and $0.084/0.765 - 0.084$. Including them gives **−1.982 nN at 10 W, or −0.668 pN at 3.37 mW**. This conditional reconstruction still does not replace measured full angular spectra or their uncertainty.

Whole optical momentum budget

$F = (P_{\text{in}} \hat{s}_{\text{in}} - \int \hat{s} dP_{\text{out}})/c$. Include reflection, transmission and diffuse scatter; add thermal radiation separately. Do not use selected efficiency as total reflectance or infer absorption as $1 - \text{selected efficiency}$.

The separate 13.343 nN reference amplitude uses assumed 10 W, 80% efficiency and $\pm 30^\circ$ states at normal incidence. It is not a prediction for this graphene device. No 10 W device power handling is asserted.

Heat is more than recoil.

Separate escaping thermal photons from fixture motion and gas-mediated effects.

Radiative bound, with declared assumptions

At an illustrative 90% absorption and 10 W input, absorbed power is 9 W. Its one-state net escaping thermal photon momentum cannot exceed $P_{\text{abs}}/c = 30.021 \text{ nN}$. This is not a predicted state difference or a measured noise floor. A difference of two states depends on both angular emission distributions; electrical heating adds to the energy budget.

A thermal number that cannot be transferred

The earlier 302.02 K example assumes two radiating faces of 0.01 m^2 each (0.02 m^2 total), emissivity 0.8, 300 K surroundings, 0.2 W absorbed power and no conductive exchange:

$$T = [T_{\text{env}}^4 + P_{\text{abs}}/(\epsilon\sigma_{\text{SB}}A_{\text{rad}})]^{1/4}.$$

Those are not the dimensions or heat-transfer conditions of Han’s device.

Effect	Required measurement
Thermal photons	State-specific absorption, spectrum, emissivity and angular emission
Mount / center of mass	Matched-heater displacement/force response versus frequency, time and temperature
Residual gas	Pressure/species sweep with controlled thermal conditions
Electrostatics and cables	Beam-off gate switching, grounded dummy, cable routing and polarity controls

P_{abs}/c does not bound thermally driven structural drift, cable tension or gas forces. A literature fixture coefficient cannot be assigned to MF-01. Lock-in detection is useful only after measuring phase, response and coherent artifacts. The Mach-Effect investigation reinforces the need to examine vibration and apparatus coupling [5].

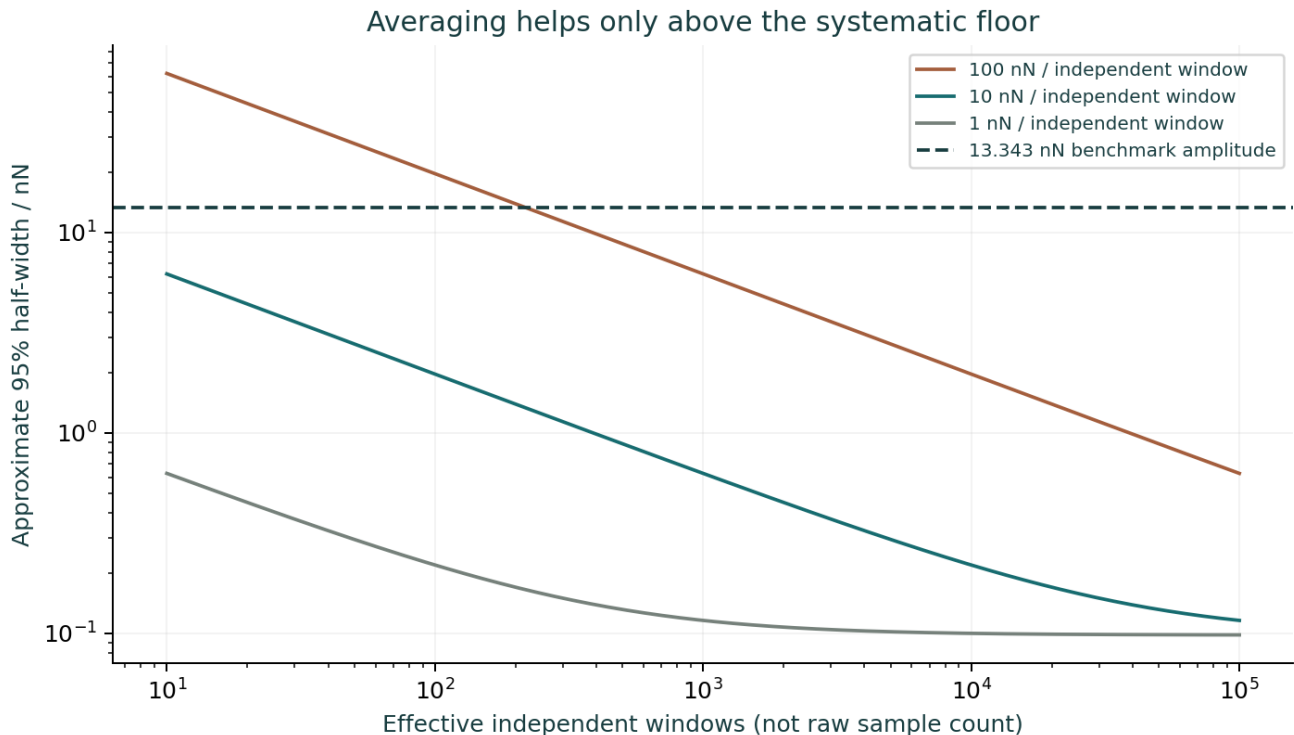
Wavelength decision

Use a provisional 1064 nm passive optical benchmark for instrument planning. Treat the $7.281 \text{ }\mu\text{m}$ graphene architecture as a separate characterization track. A qualified experimental lead must select the actual laser, coating, readout, irradiance, thermal path and safety controls; none has been procured or qualified here.

An uncertainty budget that can fail.

Noise, sensitivity and total measurement uncertainty are different quantities.

For equally allocated independent A/B windows, full difference $D = \text{mean}(F_B) - \text{mean}(F_A)$ has $u(D) = 2\sigma/\sqrt{N}$. Symmetric amplitude $a = D/2$ has $u(a) = \sigma/\sqrt{N}$. Adding a non-averaging amplitude standard uncertainty u_{sys} gives $u(a) = \sqrt{(\sigma^2/N + u_{\text{sys}}^2)}$.



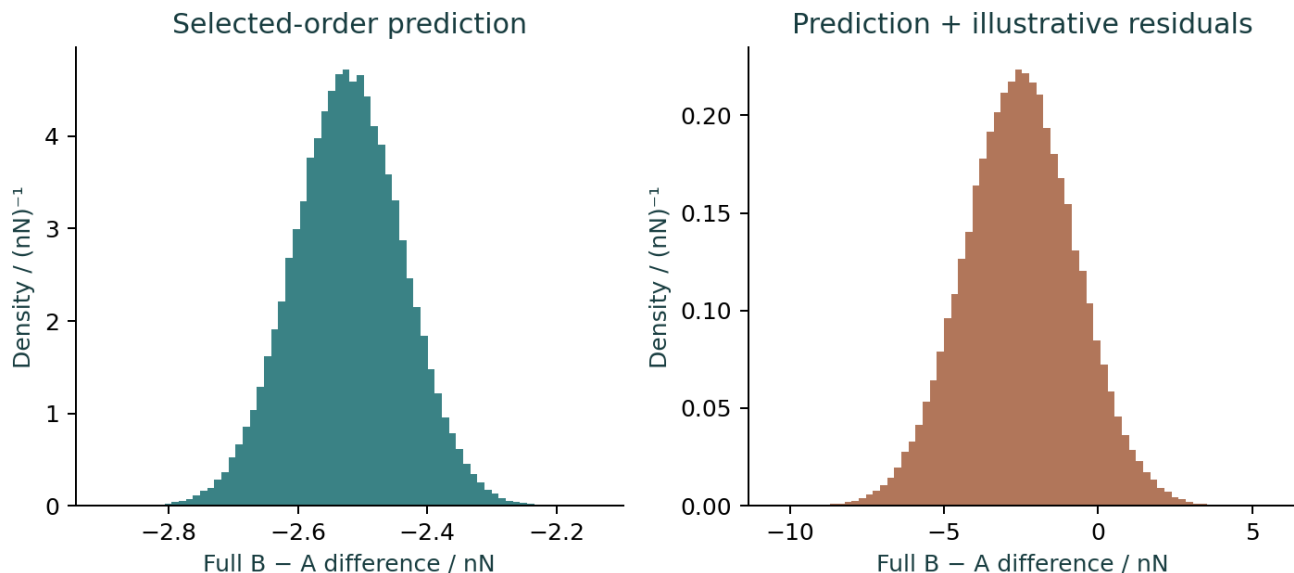
At $N = 128$ and $u_{\text{sys}} = 0.05$ nN, 100/10/1 nN per-window noise gives approximate 95% half-widths 17.324/1.735/0.199 nN. The 100 nN band does not separate the 13.343 nN benchmark amplitude from zero by that interval. The 217-window example is arithmetic, not a prospective detection-power calculation.

Raw sample count is not effective independent windows. Measure correlation and drift; characterize stability versus averaging time and reassembly. A systematic floor does not average down. Before collecting decisive data, freeze interval method, coverage, detection power and acceptance tolerance. Commissioning bands are goals, not demonstrated specifications. [6,7]

Simulation exposes assumptions.

200,000 draws · seed 20261020 · no measured instrument inputs.

200,000 simulated draws · assumptions, not instrument data



The selected-order prediction has simulated standard uncertainty 0.085 nN. The illustrative full-difference residual has standard uncertainty 1.801 nN. The combined central 95% interval is [-6.065, 1.020] nN. These values demonstrate propagation, not device performance.

Inputs: $P = 10 \pm 0.05$ W (standard uncertainty); efficiencies (0.078, 0.084) with standard uncertainties 0.003 each and correlation 0.5; angle standard uncertainties 0.2° . These uncertainties are analyst-selected, not extracted measurement errors.

Residual assumptions: absorption Uniform(0.85,0.95); effective differential thermal angular factor with standard deviation 0.01; mount coefficient 2 nN/K and differential temperature standard deviation 0.02 K, with thermal/mount correlation 0.6. Patch, gas and electrical residuals use centered uniform half-widths 0.1, 0.2 and 0.05 nN. Full-difference readout standard uncertainty is $2 \times 10 / \sqrt{128}$ nN.

All remaining inputs are independent. The source and protocol declare every distribution. Real budgets require measured distributions, covariance and justified bounds. Gaussian approximations and unresolved other optical orders limit this example. Following GUM-style propagation does not establish empirical GUM compliance or calibration [6,7].

Freeze the experiment first.

Protocol draft v0.2 is supplied as a separate, editable file. It is not registered.

MF-01A / recover a known force

Specify application point, reference, calibration chain, bandwidth and time window. Recover reference forces across the target range before and after a run. Preserve zero-input records, drift, hysteresis and alignment evidence.

MF-01B / measure the alternatives

Interleave beam-off electrical switching, fixed electrical state with optical modulation, matched-heater controls, dummy samples and pressure/temperature sweeps. Record auxiliary channels synchronously. Map phase and time response. Repeat after reassembly.

MF-01C / close optical momentum

Measure full outgoing spectra before unblinding the force result. Freeze the prediction, randomized balanced sequence, exclusions, sample-size rationale, covariance and analysis-code hash. Analyze signed $B - A$ differences, predicted scaling and null geometries. Maintain the external light-source momentum ledger.

A useful null is still a result

Reject windows only for predefined instrument faults, preserve an exclusion log and report an all-window sensitivity analysis. An unresolved artifact means HOLD. A quantitative bound requires a qualified instrument, a specified nonzero prediction and adequate controls. Independent reproduction on another team's apparatus is a separate gate.

A reproducible record

Future release: raw data, calibration, environmental records, sample stack, drawings, bill of materials, software environment, code hashes, preregistration identifier, deviations and signed review. This release contains calculations only. Source code passes 24 checks, including 19 inherited analytical/numerical checks; passing software tests is not physical validation.

What advances the project now.

Review, capability and credible decisions precede a propulsion claim.

Technical ownership

Christopher Hill remains founder and program sponsor. Recruit a qualified experimental PI, force-metrology lead and independent theory reviewer. Their roles are unfilled; no names or credentials are invented. No independently assessed venture TRL is assigned. Mature components or external papers do not transfer readiness to a complete drive.

Preparation milestones

First 30-day planning interval: seek specialist review, freeze the observable and reproduce constraint mappings. Next 30: scope lab access, component requirements, reference calibration, thermal measurements and costs. Final 30: freeze protocol and release plan only if earlier gates pass. These are proposed intervals, not promises of completed experiments or maturity increases.

Agency discussion

A suitable inquiry asks for technical feedback and the relevant program route for a metrology/optical-force feasibility study. Funding eligibility, team capability, current solicitation fit and permitted submission channels must be established separately. The public technical release contains no personal routing instruction, institutional partnership, funding award or endorsement. No email or proposal was submitted by preparing this package.

AI and audit disclosure

ChatGPT/Codex assisted source checks, model code, calculations and writing on 20 October 2026; exact model identifier was not exposed. Independent specialist review remains pending. The audit score was not treated as a probability. The original model already contained source/target momentum accounting. Its NASA routing material was removed from the current public package.

The supplied arXiv:1312.3259 link does not identify the claimed structured-Casimir paper. The NIST 2024 paper already appears in the atlas under its published title, Practical realization of the watt from Planck's constant using radiation pressure (10.1088/1681-7575/ad844b). No absent NEA Scout statement was claimed to be corrected.

Trace the evidence.

Targeted primary-source review, not an exhaustive systematic review. Numbers in brackets refer to the records below.

01 / Single-gate electro-optic beam switching metasurfaces

Sangjun Han; Jinseok Kong; Junho Choi; Won Chegal; Min Seok Jang. 2025. Light: Science & Applications 14, 292.

[10.1038/s41377-025-01967-y](https://doi.org/10.1038/s41377-025-01967-y)

Publisher PDF: relevant geometry, efficiency definitions and Methods inspected.

02 / Review of short-range gravity experiments in the LHC era

Jiro Murata; Saki Tanaka. 2015. Classical and Quantum Gravity 32, 033001.

[10.1088/0264-9381/32/3/033001](https://doi.org/10.1088/0264-9381/32/3/033001)

Author manuscript: relevant equations, constraints section and bibliographic record inspected.

03 / Test of the Equivalence Principle for Superconductors

M. P. Ross et al.. 2024. arXiv:2407.21232, author preprint.

[10.48550/arXiv.2407.21232](https://doi.org/10.48550/arXiv.2407.21232)

Author-repository abstract and version metadata inspected; not full-text review.

04 / Equilibrium forces on non-reciprocal materials

David Gelbwaser-Klimovsky; Noah Graham; Mehran Kardar; Matthias Krüger. 2022. Physical Review B 106, 115106.

[10.1103/PhysRevB.106.115106](https://doi.org/10.1103/PhysRevB.106.115106)

Author-repository abstract and journal metadata inspected; not full-text review.

Trace the evidence / continued.

Original sources retain their authorship. Publication is not an endorsement of Metric Flight.

05 / Experimental investigation of Mach-Effect thrusters on torsion balances

Maxime Monette; Matthias Kößling; Martin Tajmar. 2021. Acta Astronautica 182, 531–546.

[10.1016/j.actaastro.2021.02.037](https://doi.org/10.1016/j.actaastro.2021.02.037)

Publisher abstract/highlights and institutional bibliographic record inspected.

06 / Evaluation of measurement data — Guide to the expression of uncertainty in measurement

Joint Committee for Guides in Metrology. 2008. JCGM 100:2008.

[10.59161/JCGM100-2008E](https://doi.org/10.59161/JCGM100-2008E)

Official BIPM publication record inspected; method reference.

07 / Evaluation of measurement data — Supplement 1: Propagation of distributions using a Monte Carlo method

Joint Committee for Guides in Metrology. 2008. JCGM 101:2008.

[10.59161/JCGM101-2008](https://doi.org/10.59161/JCGM101-2008)

Official BIPM publication record inspected; method reference.

08 / Controlling the sign of optical forces using metaoptics

Adeel Afridi; Bruno Melo; Nadine Meyer; Romain Quidant. 2026. Nature Communications 17, 1163.

[10.1038/s41467-025-67928-6](https://doi.org/10.1038/s41467-025-67928-6)

Publisher full text: relevant geometry, illumination and force-readout sections inspected.