Field-based Analysis of Correlations in Solid-state HHG

Author

Avi Hadar
Email: avihadar0577@gmail.com
ORCID: 0000-0002-0979-9861

Abstract High-harmonic generation (HHG) in solids is commonly analyzed by combining Maxwell's equations with semiconductor Bloch dynamics and then characterizing the emitted light via mode-resolved photon correlations. This short note adds a complementary, purely field-level perspective aligned with a "field-preservation" kinematic rule used in my framework. The key point is simple: if a bound negative field structure undergoes periodic motion under a strong external driving field, and its effective field-radius contracts according to

$$r(v) = r_0\sqrt{1 - \frac{v^2}{c^2}},$$

then the resulting electric field amplitude becomes a nonlinear periodic function of time. Any nonlinear periodic waveform necessarily contains harmonics in its Fourier spectrum. Maxwell's equations then map the time-varying electric field / polarization source to an emitted electromagnetic field containing the same harmonic content. This provides a direct, constructive bridge from bound-field oscillation (no detachment/flow) to harmonic-rich radiation.

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1. Physical setting (minimal)

Consider a solid driven by a strong, coherent optical field. In the generation region, the relevant classical-level objects are the macroscopic polarization $P(t)$ and/or current $J(t)$ acting as sources in Maxwell's equations. HHG is observed in the emitted electromagnetic field outside the sample.

This note adopts a field-based viewpoint: - The negative field around matter is treated as a bound field configuration in the resting state (not a free particle). - Under driving, the configuration oscillates (periodic motion and deformation) but remains bound (no detachment/flow).

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2. What is measured in HHG

Experiments do not directly measure microscopic trajectories. They measure the emitted electromagnetic field: - spectral intensity (harmonic peaks), - phase/coherence, - and, in quantum-optical analyses, correlations after spectral filtering.

Thus, if one can construct a time-domain electric-field waveform $E(t)$ (or source waveform $P(t), J(t)$) that is periodic but nonlinear, the existence of harmonics follows immediately by Fourier analysis.

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3. Field-preservation kinematics (radius under motion)

In the field-relativity / field-preservation formulation, the effective radius of the bound field configuration under motion is:

$$r(v) = r_0\sqrt{1 - \frac{v^2}{c^2}}.$$

For a periodic drive, model the field speed as:

$$v(t) = v_0 \sin(\omega t).$$

Then the time-dependent radius is:

$$r(t) = r_0\sqrt{1 - \beta_0^2 \sin^2(\omega t)},$$

where $\beta_0 = v_0/c$.

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4. From $r(t)$ to a nonlinear electric-field waveform $E(t)$

Assuming a generic scaling of field strength with geometry:

$$E(t) \propto \frac{1}{r(t)^2} = \frac{1}{r_0^2\left(1 - \beta_0^2 \sin^2(\omega t)\right)}.$$

This function is periodic (with period $2\pi/\omega$) but nonlinear. By Fourier theory, any such periodic non-sinusoidal function admits a harmonic expansion:

$$E(t) = \sum_{n=0}^{\infty} a_n \cos(2n\omega t).$$

Note: The appearance of only even harmonics (via $\sin^2(\omega t)$) reflects the symmetry. In real systems, broken symmetry yields odd harmonics too.

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5. From nonlinear source to emitted EM field (Maxwell link)

The macroscopic polarization $P(t)$ and current $J(t)$ act as sources in Maxwell's equations. Typically:

$$J(t) = \frac{dP(t)}{dt}.$$

A nonlinear periodic source implies a nonlinear periodic emitted field. The radiated electric and magnetic fields carry the same spectral content.

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6. Bound vs. detached distinction

This construction does **not** require detachment (free flow of charge). It is based purely on: - bound field oscillation ⇒ nonlinear waveform ⇒ harmonics.

Breakdown of harmonic structure (and onset of heating/noise) can indicate crossing into the detached regime.

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7. Relation to modal/correlation analyses

This is complementary to modal quantum-optical analyses (e.g. $g^{(n)}$ functions): - Those describe measurement-level correlations. - This note provides a field-level mechanism that seeds such structure before projection.

References

[1] Theidel et al., *Phys. Rev. X Quantum* 5 (2024): 040319.
[2] Theidel et al., *Phys. Rev. Research* 7 (2025): 033223.