Comment on "Observation of Optical Precursors in Water"

The Letter of Choi and Österberg [1] on linear propagation measures the energy of a 660–740-nm red laser pulse traveling 4.7 m in deionized water. The Letter's title-precursor claim relies largely on a const$/z$ fit to energy at the four largest of 24 distances z. Unfortunately, the pulse cannot go as $1/z$ forever because theory [2] forces the same pulse's energy to decay faster than a pure exponential specified below. But the data [1] and theory [2] do agree for distances spanning 3.7 decades in Fig. 1. Because the Letter and the earlier prediction [2] were unaware of each other, this is strong evidence that the raw data and the prediction are both correct. But the Letter's first-paragraph extrapolation of the four-point, $1/z$ fit is inconsistent with the theory of exponential decay that Fig. 1 verifies here with 24 points.

In fact, any linear pulse whose finite-width spectrum is separated from dc has normalized energy $\bar{\mathcal{E}}(z) = \mathcal{E}(z)/\mathcal{E}(0)$ that satisfies $\bar{\mathcal{E}}(z) \leq \exp(-\alpha_{\min} z)$. Here $\alpha_{\min}$ is water's minimum absorption coefficient for 660–740 nm and $\mathcal{E}(z) = \int |E|^2 dt = \int |\tilde{E}|^2 d\omega$ [2]. Normalized peaks $\bar{p}(z) = p(z)/p(0)$ of $|E(z,t)|$ satisfy $\bar{p}(z) \leq \exp(-\alpha_{\min} z/2)$. The derivations [3] have five steps and are suitable for some advanced undergraduates. The mathematics of the Fourier transform, however, requires every finite-band pulse to extend from time $-\infty$ to $+\infty$ with no quiescent interval. Fortunately, band-limited pulses behave nearly as limited-duration pulses do in eight numerical examples [2] and here in Fig. 1.

For several water references, including [4] used by the Letter, $\alpha_{\min} = \alpha(660\ \text{nm})$. But $\alpha(660\ \text{nm})$ of [4] is from [5], in which $\alpha(660\ \text{nm})$ is nearly the mean value of (a) a measurement of twice-distilled water [6] and (b) an estimate involving the Sargasso Sea and Crater Lake National Park, USA [7]. It is better to omit part (b) and so represent the Letter's deionized water by twice-distilled water, using $\alpha_{\min} = 0.305/\text{m}$ from [6]. The Letter's use of a less-relevant mixed-water value, $0.358/\text{m}$ from [4,5], contributes to the top line of Fig. 1 of [1] being below the 4.7 m datum.

Relevant to the purpose of [1], algebraic decay ($z^{-\text{const}}$) of amplitudes was reported earlier for theoretical and real pulses whose spectra include dc. Examples of $z^{-1/3}$ and $z^{-2/3}$ decay follow from textbook theory [8]. Measurements of dc-content, microwave pulses in coaxial cables filled with water and concrete show algebraic decay and spread, evinced by nearly straight segments on log-log graphs [9]. Those data agree reasonably well with Debye- and Lorentz-model asymptotic theories. In that research, a measurement group and two theory groups were unaware of each other's work until final results were compared [9].

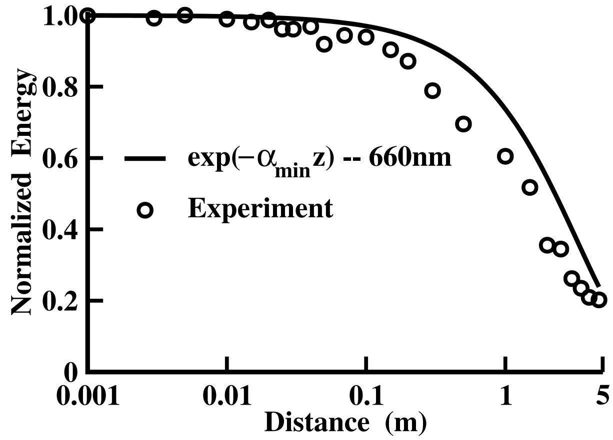

FIG. 1. The data and the prediction $\bar{\mathcal{E}}(z) \leq \exp(-\alpha_{\min} z)$ agree for distances spanning 3.7 decades.

That coincidence resembles the present circumstance of mutual verification by completely independent measurements [1] and theory [2] with spectra separated from dc.

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