

rate and other factors. Also, the term comes from "roentgen equivalent man," not "roentgen-equivalent for mammals."

The roentgen, a special unit for measuring exposure to x or gamma rays in air, is not a measure of "the amount of ionizing radiation. . . ." Rather, it is a measure of the amount of ionization produced in air by x or gamma radiation. An exposure of 1 roentgen occurs when the sum of electrical charges on all ions of one sign produced by x or gamma rays in 1 kg of air is 0.000258 coulombs. The definition of the roentgen does not depend on temperature and pressure, although the exposure does depend on the energy and number of x or gamma photons.

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[Editor's Note: We appreciate having our glossary updated.]

The 'Atom Laser' and the Constructs of Physicists—Revisited

Daniel Kleppner's excellent essay on the "atom laser" in your August 1997 issue (page 11) still left me feeling, well, a bit obdurate, in that I believe a person literate enough to have "obdurate" in his active vocabulary (see page 13 of the essay) should be deploring, not advocating, use of an expression as misleading as "atom laser."

Before reading the essay, I might have guessed that an "atom laser" was either an abstraction (a single atomic transition being regarded as laserlike) or some sort of optical trap that holds atoms in rigid positions with the result that they lase. After having read the essay, I find that either mono-energetic atoms or a narrow beam of atoms would have been equally plausible alternative interpretations.

Even for physicists, "atom laser" is a clumsy construct for describing a coherent source of atoms. Despite the adjectival structure, "atom" doesn't modify "laser" here but *vice versa*, and that cannot be fixed because "laser atom" would almost irresistibly be interpreted as an atom involved in lasing. Worse, there is nothing in the acronym "laser" that directly connotes "coherent" (nor, for that matter, the other standard attributes of laser light: being near-mono-energetic or highly collimated).

However, all this suggests the pos-

sibility of a pastime wherein one couples nouns with other inappropriate objects and tries to figure out an interpretation, such as "neutron radio" or "atom rose." Obviously, atom rose refers to copper since roses are red and copper is the red metal. Of course, not all roses are red, so the door is opened to confusion with silver, gold etc. But what the heck, everyone else is supposed to know what I mean, even if I myself can't enunciate it.

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Daniel Kleppner's columns are always informative and entertaining, the first thing I turn to in PHYSICS TODAY. Semantic arguments are often pointless, but I'm afraid his August 1997 essay fails to give me a better understanding of why an atom laser should be called a laser.

The essential aspect of a maser or laser is, as the acronyms essentially say, "amplification by stimulated emission of radiation." Note that the primary term is "amplification," not "oscillation." This phrase is most often interpreted, moreover, as referring to the kind of linear, phase-preserving amplification that comes when the radiation passes through some kind of reservoir that can reasonably be described by an "inversion," or a negative temperature.

In addition, although there is a certain crucially important coherence at the atomic level involved in the way the amplifying atoms in a laser respond to the radiation passing through it, the coherence (spatial or temporal) of the output from a device really has nothing at all to do with whether a device is a laser or not. X-ray lasers and certain mirrorless semiconductor and erbium fiber lasers, and also other kinds of mirrorless amplified spontaneous emission (ASE) lasers, are definitely lasers despite having almost totally incoherent outputs. The outputs of two ASE lasers will not interfere, at least not at the level considered by Kleppner. Astronomical masers and lasers have essentially incoherent outputs, yet are clearly maser or laser phenomena.

The outputs from optical parametric oscillators, on the other hand, can be every bit as coherent as those from laser oscillators, and can have statistical properties pretty much indistinguishable from those of lasers; yet OPOs are definitely not lasers. The outputs from certain atomic or magnetic resonance "coherent pulse" experiments can have strong coher-

ence properties, and such devices make use of very laserlike collections of prepared two-level atoms; but they're not really masers or lasers either. Stimulated Brillouin and Raman devices can produce pretty coherent outputs, but "Raman lasers" are not (at least in my book) really lasers. Free-electron lasers are not, except in a tortured interpretation, really lasers, or at least if they're laser devices, then so are microwave traveling-wave tubes, and the whole meaning of "laser" becomes too nebulous to be worth worrying about.

To be sure, the "radiation" referred to by the final "r" in "maser" and "laser" can be interpreted very broadly, and need not be light or microwaves. Audio and radio frequency magnetic-resonance masers operate much more in the lumped-circuit regime than the wave or radiation regime. And the purely acoustic masers demonstrated some decades ago were, beyond doubt, maser devices, although they worked entirely with acoustic rather than electromagnetic waves (they used stimulated emission to amplify phonons rather than photons).

Perhaps there's a maser or laser process for atom waves also. Nevertheless, the macroscopic coherence properties associated with atom lasers don't (necessarily) make them lasers, and, in this case, Kleppner's essay remains unconvincing.

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KLEPPNER REPLIES: I regret having caused Curtis Michel to feel obdurate as a result of encountering the term "atom laser," but, as I cautioned, ink has been spilled and friendships lost over such matters. However, I can see his point: As a modifier, "atom" would suggest the atom laser radiates light, not atoms, just as the ion laser radiates light, not ions. Nevertheless, the "atom" in "atom laser" is not an adjective but a noun, for the term "atom laser" is a compound noun. (A colleague in linguistics explained to me that the glory of English is that it is the only language in which you can verb a noun and noun a verb; in such a language, compounding a noun is peanuts.) Another example of this usage is the "phonon maser" proposed by Charles Townes and Nicolaas Bloembergen, as cited by Lee Casperson in his letter (PHYSICS TODAY, November 1997, page 15). With respect to whether a mono-energetic or well-collimated atomic beam constitutes a laser, such a beam could display first-order coherence only,

not higher-order coherence. In any case, by the time the beam would be collimated enough to search for coherence, its intensity would be effectively zero.

Anthony Siegman is not concerned with semantics but with physics. For him the distinguishing feature of a laser is its role as an amplifier, rather than the coherence properties that I emphasized. However, it seems to me that even from this point of view the term "atom laser" is apt. As I described, the field in an atom laser—the atom field of the system's ground state—grows by stimulated scattering, in close analogy with stimulated emission in a laser. From this point of view, the atom laser demonstrates amplified spontaneous scattering (I forgo the acronym), in close analogy to the ASE laser he cites.

Because of the differing views on what constitutes a laser, I understand why "atom laser" might be regarded as a misnomer. Nevertheless, it still seems to me that it is a pretty good nomer.

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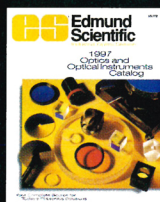
The Constructs of Physics and the Role of Math—Revisited

I never had a formal education in philosophy, nor do I think my epistemological insights gained from lifelong research are particularly deep; nevertheless, I think that there is something very wrong with Lorenzo de la Torre's letter (PHYSICS TODAY, September 1997, page 15).

I believe the following quotes from his letter summarize his views: "[P]hysical reality is, to some extent, a *construct* of our own; . . . we *construct* physical reality so that it complies with mathematics. . . . [M]athematics is inherent in the *construction* of . . . physical reality" (emphases added).

Although I am certainly not a rabid materialist, I must take issue with his ultraidealistic views. I fully agree with him when he says that "[t]he use of quantities in theoretical explanations and predictions, and in the analysis of experimental data, is innately connected to mathematics. Physics characteristically looks for natural laws that have a mathematical structure." Sure—but we do not *construct* reality, either with or without mathematics! At the very best, we construct something like "images

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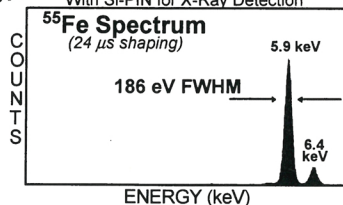
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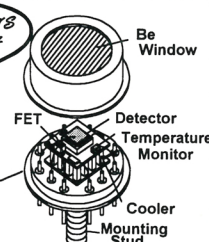
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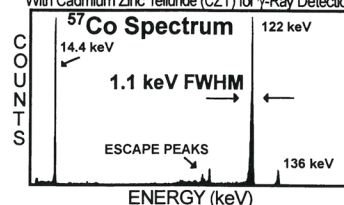


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