Physics in Medicine: Bridging the Gap

Stephen Skolnick
Public Outreach Intern
American Physical Society
BS Applied Physics 2014—Indiana University

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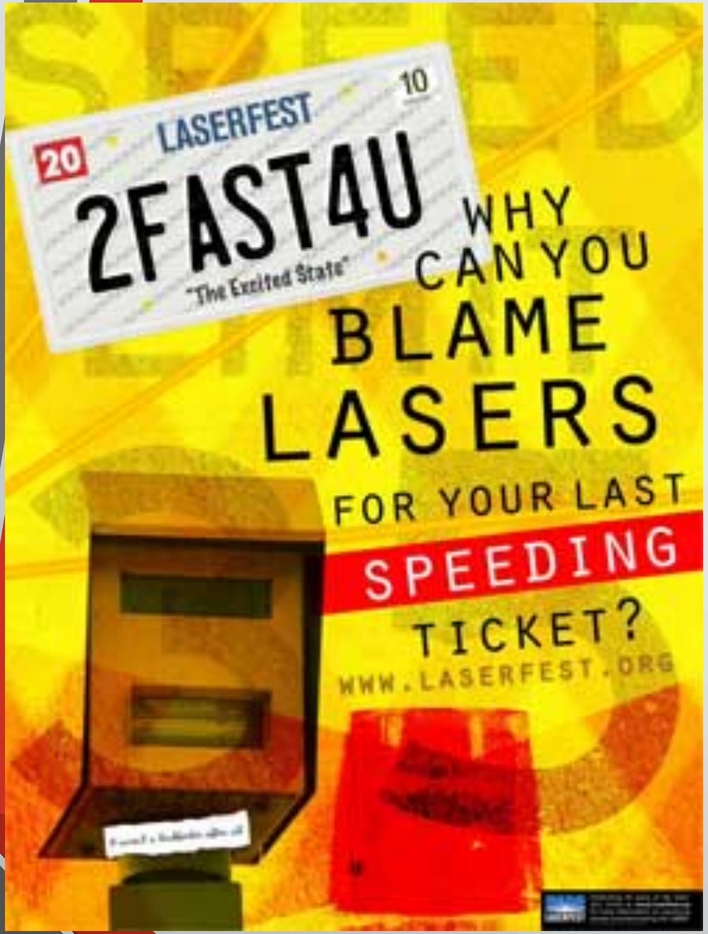
Precedent: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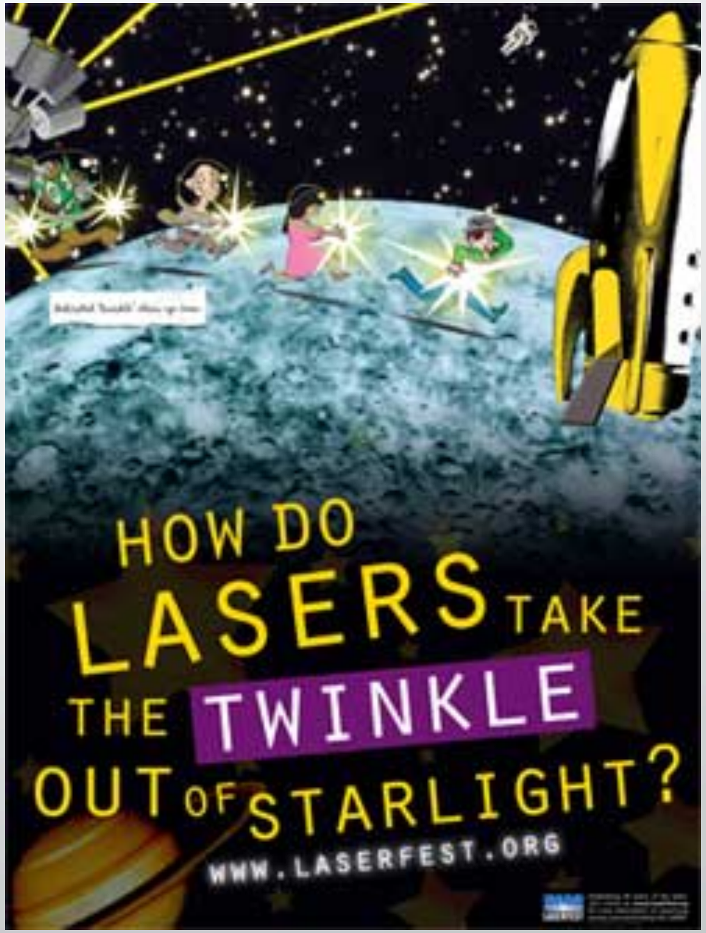
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How Do Lasers Help Create Both the Coldest and Hottest Spots on Earth?

Laser Cooling

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Scientists are using lasers to cool atoms to extremely low temperatures. But what does it mean to "cool" atoms? Atoms are constantly in motion, so cooling atoms to low temperatures essentially amounts to reducing their motion or speed.

The basic principle behind laser cooling is that light, in addition to carrying energy E, also carries momentum p, with $p = E/c$ (c is the speed of light). This momentum can be transferred to an object to generate a force. For atoms, it is useful to consider the light from the laser as consisting of photons. If an atom moving in some direction absorbs a photon from a laser beam propagating in the opposite direction, the atom's velocity will decrease.

The atom subsequently emits the photon by spontaneous emission; yet the average velocity change due to this process is zero, since the photon is emitted in a random direction. By repeating this process of absorption followed by spontaneous emission many times, it is possible to significantly lower the velocity and hence kinetic energy of an atom, thereby "cooling" it down.

A major requirement of this laser cooling scheme is that photon absorption takes place preferentially, when the atoms are moving against the flow of photons from a laser beam. To ensure this happens, scientists use the Doppler shift associated with the motion of the atom. Similar to the change in pitch of a train whistle as the train approaches and passes by an observer, an atom will experience a shift in the apparent frequency of light due to the relative motion of the atom and the source of light. An atom moving towards a laser observes that the laser light is at a slightly higher frequency, due to the Doppler shift. Likewise, an atom moving away from a laser observes that the laser light is at a slightly lower frequency.

Hence, by tuning the laser to emit light at a frequency slightly lower than the frequency required to be absorbed by the atom at rest, it is more likely that the light will be absorbed if the atom is moving towards the laser than if the atom is moving away from the laser. The atom moving towards the laser will "see" a frequency that is closer to the ideal frequency for absorption, while an atom moving away from the laser will experience a frequency further away from the ideal frequency for absorption.

This type of laser cooling is known as, "Doppler cooling" and was first demonstrated 1985, by Steven Chu and colleagues, then at Bell Labs. Their experiment consisted of six laser beams arranged in such a manner that they cooled sodium atoms in a vacuum. The atoms in this laser beam configuration experience a viscous force, which tends to dampen their motion, prompting Chu and colleagues to refer to it as, "optical molasses". Doppler cooling typically results in temperatures for the atoms in the

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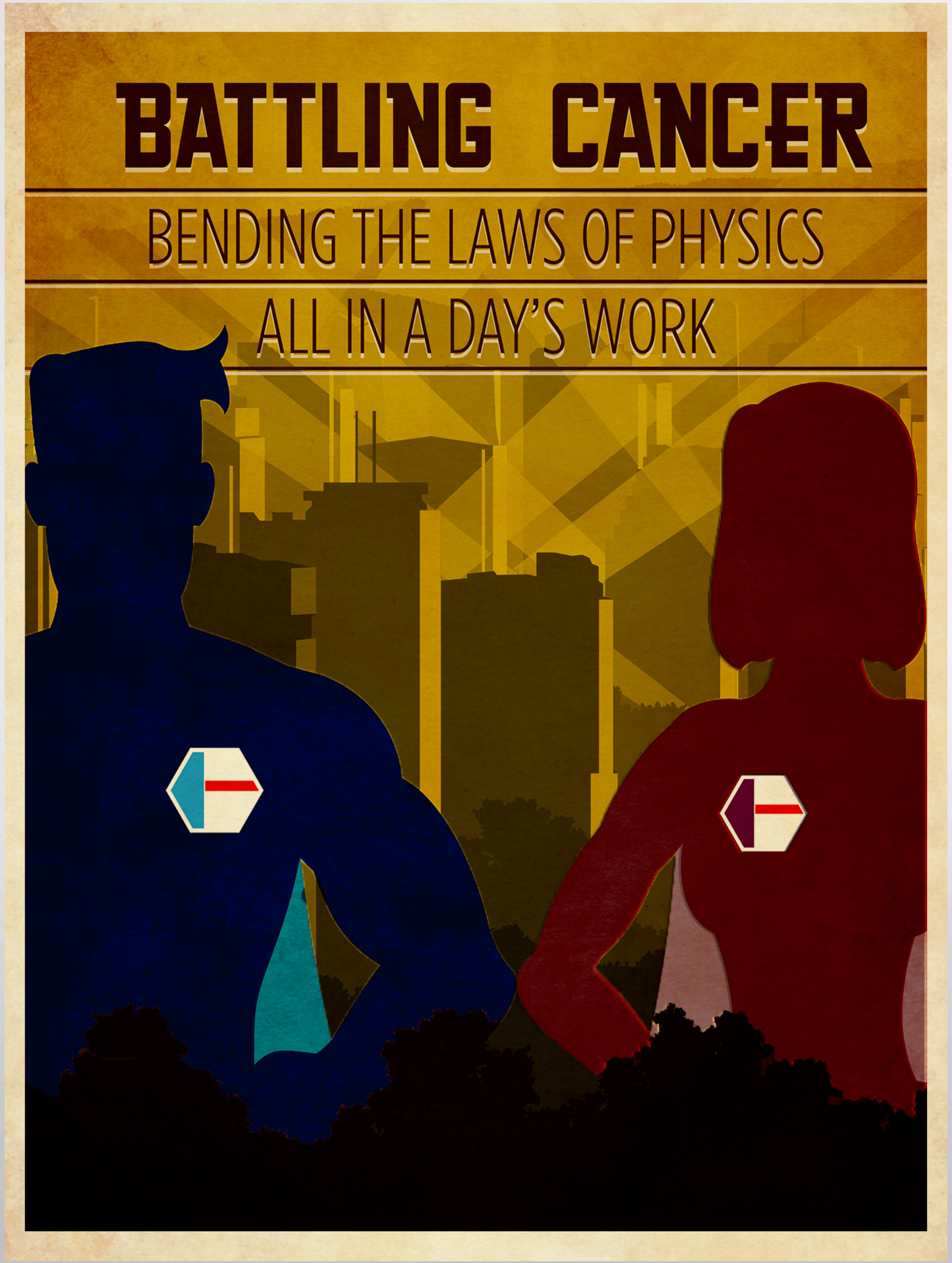
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ALL IN A DAY'S WORK

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Thank You!