Self-ticking oscillator could be next for portable atomic clocks

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"Most conventional atomic clocks need a more conventional, non-atomic clock, like a quartz crystal, to keep them ticking," William Happer tells *PhysOrg.com*. "We've developed a system that would be self-ticking, using a specific laser."

Happer is a scientist at Princeton University. He, along with his young colleague Yuan-Yu Jau, invented a push-pull laser-atomic oscillator that can be useful in a variety of applications, including questions of fundamental physics, use in portable atomic clocks and coherent optical combs. "We didn't start out thinking about applications, really," Happer says. "We're physicists. We just wanted to see if we could make this type of oscillator work." The results of Happer and Jau's work can be found in *Physical Review Letters*: "Push-Pull Laser-Atomic Oscillator."

Jau explains that even though they didn't set out to build a better portable atomic clock, he thinks that they have succeeded. "We believe this is the first demonstration of making an oscillator that produces an atomic-clock signal in both electrical and optical forms by purely optical means," he says. "This is simple. There are fewer components and lower power consumption."

"The new clock needs neither a quartz crystal with its electronics nor a photodetector," Happer adds.

Jau and Happer explain that in conventional atomic clocks, a quartz crystal is used "as a flywheel to keep the clock ticking strongly, with the atoms as a weak controlling element." They point out that if the quartz crystal fails, the clock will cease working. "These are the types of clocks used in GPS satellites and in cell-phone towers," Happer says.

Jau points out that better precision is becoming increasingly necessary: "Mini atomic clocks can be helpful. There are many systems now working faster and faster, and transmitting large quantities of data, especially in high-speed communications. A laser atomic clock like this would be less complicated than the conventional kind, with comparable precision."

The push-pull laser-atomic oscillator built by the two consists of a semiconductor laser with alkali-metal vapor (in this case Potassium) in the external cavity. A time independent current is used to pump the semiconductor laser. "The laser will automatically modulate its light and its electrical impedance at the clock frequency of the atoms," Happer says. This in turn eliminates the need for an external modulator, like the quartz crystal, or for a photodetector.

"It's really a souped-up mode-locked laser," Happer says. "While our laser has much in common with a mode-locked laser, there are some differences. The atoms in the vapor cell notice if the frequency of the mode-locked laser drifts and they automatically correct the frequency with no need for any external feedback loops."

Happer continues: "An important benefit of push-pull pumping with alternating circular polarization is that none of the atoms are wasted."

"In most atomic clocks," Jau adds, "many of the atoms are wasted. Only a very few are in the clock state. With this push-pull pumping, all of the atoms are put into a clock state."

Along the way, the two discovered something interesting. "The selfmodulation occurs over a limited range of laser injection current. We weren't surprised that too little current didn't work. What surprised us was that too much current caused the laser to stop modulating," Happer says.

Jau continues: "This new oscillator, where the polarized atoms, the modulated photons, and the laser gain centers are all coupled together has very rich and interesting physics. "

Happer does point out that these oscillators could not replace the extremely precise, but large atomic clocks that occupy whole rooms. "It's really to improve the workings of small, portable atomic clocks," he emphasizes. "It eliminates the need for quartz crystals or photodetectors. Hopefully, with fewer parts, it will be less expensive to manufacture, and more stable."

Jau agrees: "This is a primitive idea, how to make an atomic clock by using pure optical methods without a quartz crystal. But it works better with reduced components and power consumption."