On-chip, electronically tunable frequency comb
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Lasers play a vital role in everything from modern communications and connectivity to bio-medicine and manufacturing. Many applications, however, require lasers that can emit multiple frequencies—colors of light—simultaneously, each precisely separated like the tooth on a comb.

Optical frequency combs are used for environmental monitoring to detect the presence of molecules, such as toxins; in astronomy for searching for exoplanets; in precision metrology and timing. However, they have remained bulky and expensive, which limited their applications. So, researchers have started to explore how to miniaturize these sources of light and integrate them onto a chip to address a wider range of applications, including telecommunications, microwave synthesis and optical ranging. But so far, on-chip frequency combs have struggled with efficiency, stability and controllability.

Now, researchers from the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) and Stanford University have developed an integrated, on-chip frequency comb that is efficient, stable and highly controllable with microwaves.

The research is published in *Nature*.

"In optical communications, if you want to send more information through a small, fiber optic cable, you need to have different colors of light that can be controlled independently," said Marko Loncar, the Tiantsai Lin Professor of Electrical Engineering at SEAS and one of the senior authors of the study. "That means you either need a hundred separate lasers or one frequency comb. We have developed a frequency comb that is an elegant, energy-efficient and integrated way to solve this problem."

Loncar and his team developed the frequency comb using lithium niobite, a material well-known for its electro-optic properties, meaning it can efficiently convert electronic signals into optical signals. Thanks to the strong electro-optical properties of lithium niobite, the team’s frequency comb spans the entire telecommunications bandwidth and has dramatically improved tunability.

"Previous on-chip frequency combs gave us only one tuning knob," said co-first author Mian Zhang, now CEO of HyperLight and formerly a postdoctoral research fellow at SEAS. "It’s a like a TV where the channel button and the volume button are the same. If you want to change the channel, you end up changing the volume too. Using the electro-optic effect of lithium niobate, we effectively separated these functionalities and now have independent control over them."

This was accomplished using microwave signals, allowing the properties of the comb—including the
bandwidth, the spacing between the teeth, the
height of lines and which frequencies are on and
off—to be tuned independently.

"Now, we can control the properties of the comb at
will pretty simply with microwaves," said Loncar.
"It's another important tool in the optical tool box."

"These compact frequency combs are especially
promising as light sources for optical
communication in data centers," said Joseph Kahn,
Professor of Electrical Engineering at Stanford and
the other senior author of the study. "In a data
center—literally a warehouse-sized building
containing thousands of computers—optical links
form a network interconnecting all the computers so
they can work together on massive computing
tasks. A frequency comb, by providing many
different colors of light, can enable many computers
to be interconnected and exchange massive
amounts of data, satisfying the future needs of data
centers and cloud computing.

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**More information:** Mian Zhang et al, Broadband
electro-optic frequency comb generation in a lithium

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