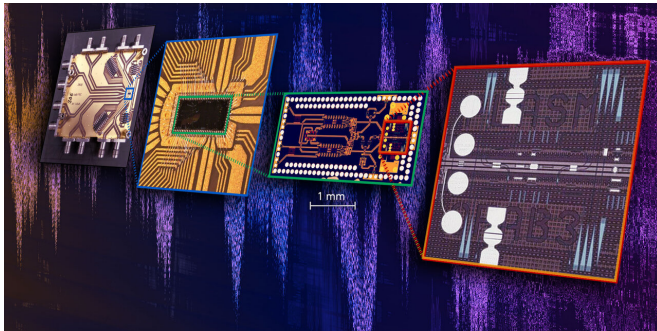


A completely new plasmonic chip for ultrafast data transmission using light

3 July 2020, by Florian Meyer



The new, highly compact chip brings together the fastest electronic and light-based elements in a single component for the first time. Credit: ETH Zurich/Nature Electronics

Researchers from ETH Zurich have achieved what scientists have been attempting to do for some 20 years: in their laboratory work as part of European Horizon 2020 research projects, they have manufactured a chip on which fast electronic signals can be converted directly into ultrafast light signals—with practically no loss of signal quality. This represents a significant breakthrough in terms of the efficiency of optical communication infrastructures that use light to transmit data, such as fiber optic networks.

In cities like Zurich, these fiber optic networks are already being used to deliver [high-speed internet](#), digital telephony, TV, and network-based video or audio services ("streaming"). However, by the end of this decade, even these optical communication networks may reach their limits when it comes to rapid data transmission.

This is due to the growing demand for online services for streaming, storage and computation, as well as the advent of artificial intelligence and 5G networks. Today's optical networks achieve data transmission rates in the region of gigabits

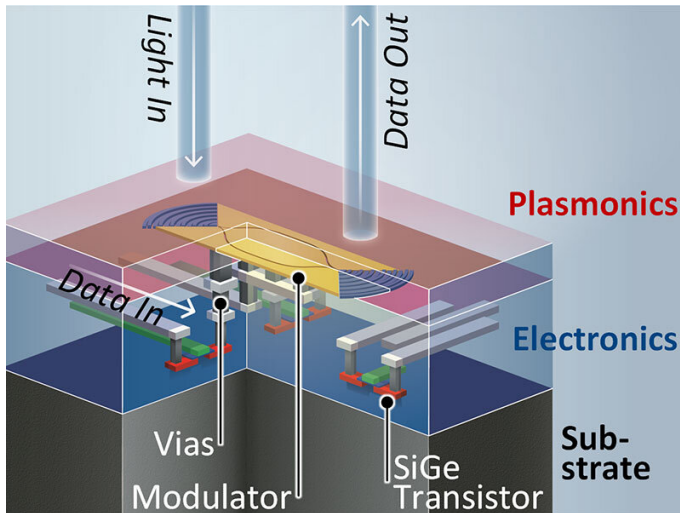
(10^9 bits) per second. The limit is around 100 gigabits per lane and wavelength. In the future, however, transmission rates will need to reach the terabit region (10^{12} bits per second).

New: electronics and light on the same chip

"The rising demand will call for new solutions," says Juerg Leuthold, ETH Professor of Photonics and Communications. "The key to this paradigm shift lies in combining electronic and photonic elements on a single [chip](#)." The field of photonics (the science of [light](#) particles) studies optical technologies for the transmission, storage and processing of information.

The ETH researchers have now achieved precisely this combination: in an experiment performed in collaboration with partners in Germany, the US, Israel and Greece, they were able to bring together electronic and light-based elements on one and the same chip for the first time. This is a huge step from a technical perspective, because these elements currently have to be manufactured on separate chips and then connected up with wires.

There are consequences to this approach: on the one hand, manufacturing the electronic and photonic chips separately is expensive. On the other hand, it hampers performance during the conversion of electronic signals into light signals and thereby limits the transmission speed in fiber optic communication networks, explains Ueli Koch, a postdoc in Leuthold's group and lead author of the study, which was published in the journal *Nature Electronics*.



failed because photonic chips are much bigger than electronic ones. This prevented them from being combined on a [single chip](#), says Juerg Leuthold. The size of the photonic elements makes it impossible to combine them with the metal oxide semiconductor (CMOS) technology that is prevalent in electronics today.

Plasmonics: magic potion for semiconductor chips

"We've now overcome the size difference between photonics and electronics by replacing the photonics with plasmonics," says Leuthold. For ten years, scientists have been predicting that plasmonics, which is a branch of photonics, could provide the foundation for ultrafast chips. Plasmonics can be used to squeeze light waves into structures that are much smaller than the wavelength of the light.

As the plasmonic chips are smaller than electronic ones, it is now actually possible to manufacture much more compact, monolithic chips that incorporate both a photonic and an electronic layer. In order to then convert the electrical signals into even faster optical ones, the photonic layer (seen in red in the graphic) contains a plasmonic intensity modulator. This is based on metal structures that channel the light in order to reach higher speeds.

Combined for record speed

This is in addition to a speed increase in the electronic layer (seen in blue in the graphic). In a process known as "4:1 multiplexing," four lower-speed input signals are bundled and amplified so that, together, they form a high-speed electrical signal. "This is then converted into a high-speed optical signal," says Koch. "In this way, we were able to transmit data on a monolithic chip at a speed of over 100 gigabits per second for the first time."

In order to reach this record-breaking speed, the researchers combined plasmonics not only with classical CMOS electronics but also with the even faster BiCMOS technology. They also made use of a new temperature-stable, electro-optical material from the University of Washington as well as

Thanks to the combination of electronics and plasmonics on a single chip, light signals can be amplified and data can be transmitted faster. Credit: IEF/Springer Nature Ltd.

Compact size for maximum speed

"If you convert the electronic signals into light signals using separate chips, you lose a significant amount of signal quality. This also limits the speed of data transmission using light," says Koch. His approach therefore begins with the modulator, a component on the chip that generates light of a given intensity by converting the electrical signals into light waves. The size of the modulator must be as small as possible in order to avoid a loss of quality and intensity in the [conversion process](#), and in order to transmit the light—or rather the data—faster than is possible today.

This compactness is achieved by placing the electronic and photonic components tightly on top of one another, like two layers, and connecting them directly to the chip by means of "on-chip vias." This layering of the electronics and photonics shortens transmission paths and reduces losses in terms of signal quality. As the electronics and photonics are implemented on one single substrate, the researchers describe this approach as "monolithic co-integration."

For the past 20 years, the monolithic approach has

insights from the Horizon 2020 projects PLASMOfab and plaCMOS. According to Leuthold, their experiment showed that these technologies can be combined to create one of the fastest compact chips: "We're convinced that this solution can also pave the way for faster data transmission in optical communication networks of the future."

More information: Ueli Koch et al. A monolithic bipolar CMOS electronic–plasmonic high-speed transmitter, *Nature Electronics* (2020). DOI: [10.1038/s41928-020-0417-9](https://doi.org/10.1038/s41928-020-0417-9)

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