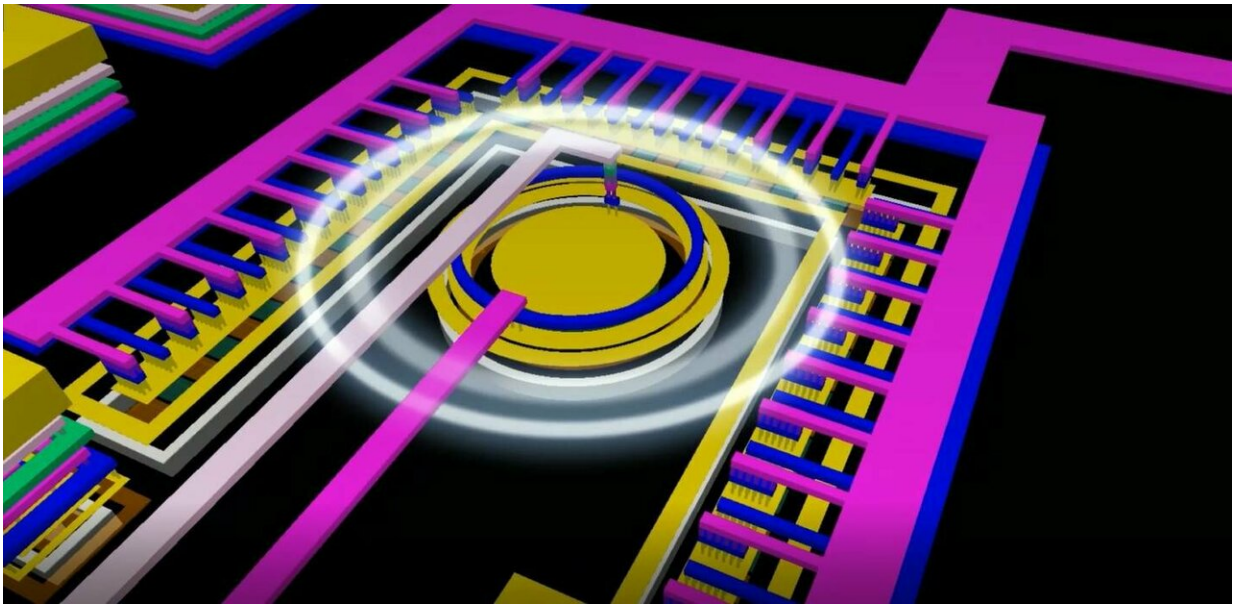
Light connects two worlds on a single chip

January 18 2019



Artist impression of the optocoupler, the round structure is the detector (Single Photon Avalanche Diode), the light source (Avalanche Mode LED) has the shape of a horse shoe. Credit: University of Twente

For the first time, researchers of the University of Twente succeeded in connecting two parts of an electronics chip using an on-chip optical link. A light connection could be a safe way of connecting a high-power component and digital control circuitry on one chip without a direct electrical link. Until now, however, an optical link was not possible using standard silicon chip technology. Vishal Agarwal, a UT Ph.D. student, managed to do so. He realized a very small optocoupler circuit that

delivers a data rate of Megabits per second in an energy-efficient way.

In 'smart power' chips, the high-power component can be isolated from the digital control circuits. This isolation guarantees safe operation in application areas like medical and automotive electronics. Until now, such optocouplers were bulky and separate from the chip. An on-chip optocoupler has now been realized by Vishal Agarwal. His optocoupler can be integrated with the electronics using standard chip technology (CMOS). It is about 0.008 mm^2 in size and consumes minimal energy.

Integrating a light source and a light detector on a chip is not trivial. In general, special materials are needed that can't be introduced in the CMOS process. Silicium is not a good light source by itself. A silicon LED on a chip would emit some infrared light with low efficiency, while a silicon detector doesn't work well with infrared light. This is not a good starting point for an optical connection. Previous research, however, by UT Ph.D. student Satadal Dutta, proved that better results can be obtained by connecting the silicon LED "the wrong way." An avalanche effect results in the emission of visible light. In the same way, a light detector can be made at which a single photon can induce an avalanche. The result: an efficient optical connection.

The principle worked. Now, for Agarwal, the challenge was to design an electronic circuit that controls the LED and the detector in the best way, optimizing for energy consumption, speed and use of space on the chip. For example he wants to balance the voltage needed for operating the avalanche-mode LED (AMLED) and the single photon avalanche diode (SPAD), resulting in a good connection without wasting light. He also needs to determine how to position the light source and light detector on the chip, for the highest efficiency. In his thesis, Agarwal comes up with an optocoupler that can be fully integrated in CMOS, with a data rate of about 1 megabit per second and minimal energy consumption.

More information: V. Agarwal. Optocoupling in CMOS, (2018). DOI: 10.3990/1.9789036547079