Popular science summary of the PhD thesis

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Title of the PhD thesis | Strategies for Hybrid Integration and Packaging at Millimeter-Wave and THz Frequencies
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Science summary

In this thesis, the strategies for hybrid integration and packaging at millimeter-wave and terahertz (THz) frequencies are investigated for different applications. The three-dimensional (3D) hybrid integration of a terabit transmitter is demonstrated. For packaging microwave integrated circuits (MICs) as well as monolithic microwave integrated circuits (MMICs) at millimeter-wave and THz frequencies, rectangular waveguide-to-coplanar waveguide (CPW) transitions are realized by using E-plane probe, wire bonding probe, and wideband patch antenna. The system integration and packaging of a THz photodetector is addressed.

As the fundamental research work for the 3D hybrid integration of the terabit transmitter, planar transmission lines including CPW, coupled coplanar waveguide (CCPW), coplanar stripline (CPS), and coupled line based on aluminum nitride (AlN) substrate are introduced. The transmission line structures, designs, and simulation methods are explained while special attention is paid to suppress parasitic modes. As a result, coplanar transitions are designed by using either wire bonding bridges together with an absorber layer or hollow plated vias going through the AlN substrate. CPW-to-CPS and CCPW-to-coupled line transitions are specialized for guiding single-ended signals and differential signal pairs, respectively. Due to the application, the designed planar transmission lines as well as coplanar transitions are emphasized on supporting data transmissions starting from DC and at the same time providing large bandwidths. By combining the designed planar transmission lines and coplanar transitions, the interposer for guiding four single-ended signals from the drivers (DRVs) to the Mach-Zehnder modulator (MZM) is formed and the 3D hybrid integration of the terabit transmitter is demonstrated.

Though rectangular waveguides are widely used as the standardized interface for connecting or cascading different components and systems at millimeter-wave and THz frequencies, the MMICs at such high frequencies still rely on planar structures. Thus, different methods and structures are invented for realizing the transitions between rectangular waveguides and planar transmission lines in particular rectangular waveguide-to-CPW transitions. The development of the packaging strategies for MMICs is based on the technical innovations of both transition methods and packaging structures. The challenges for designing rectangular waveguide-to-CPW transitions are achieving a wideband matching with low insertion loss and being versatile at the same time for packaging the existing components and chips. As novel methods, the transitions based on quartz substrate using wire bonding probe and wideband patch antenna are proposed and compared with the transitions using E-plane probe. Besides, the 3D printing and copper plating processes are tested due to the potential of fabricating the packaging structures at millimeter-wave and THz frequencies.

A THz photodetector is implemented by integrating a photoconductor with a feeding network, a bias-tee, and a rectangular waveguide-to-CPW transition. As an electro-optic device used for converting signals from optical domain to electrical domain, the photodetector can be applied on both the transmitter and the receiver sides in THz communication systems. The principal components are designed individually while the chip-level connections and the packaging structures are also described. The assembly structure is demonstrated and the packaging strategy is addressed.

Please email the summary to the PhD secretary at the department.