40 Years of Semiconductor Lasers
A Tribute to Markus-Christian Amann

(Invited paper)

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ABSTRACT

For over 40 years Markus-Christian Amann (MCA) was a prominent member of the semiconductor laser community, and made numerous significant contributions to a wide range of topics. In this presentation we will review some of these contributions. We will also add some comments of a more personal character.

Keywords: Markus-Christian Amann, ridge waveguide lasers, tunable lasers, VCSELs, quantum cascade lasers.

SUMMARY

MCA started his work on AlGaAs/GaAs lasers in the late 70ies. At that time laser structures were grown by LPE, making thickness control difficult, and regrowth impossible. Simple stripe geometry structures suffered from numerous problems, making their practical use difficult. A relatively simple solution developed by MCA was the metal clad ridge waveguide (MCRW) laser. When GaInAsP/InP lasers were developed in the early 80ies the MCRW design was successfully applied to fabricate weakly index guided long wavelength lasers by a comparatively simple process.

In the early 90ies during his time as an employee of Siemens research laboratories MCA became a world leading expert on tunable lasers, inventing several different designs. The tunable twin-guide (TTG) laser is a particularly elegant design, allowing continuous electronic tuning in excess of 10 nm. Other ideas include: 1) the vertical Mach-Zehnder (VMZ) using two layers rather than two branches, 2) the amplifier-coupler-absorber (ACA) using a codirectional grating assisted coupler, and 3) the distributed forward coupled (DFC) structure. For all of these structures MCA provided both the basic idea and the detailed design. One of the results on the work on tunable lasers was the book “Tunable Laser Diodes”, published in 1998, and later updated and expanded in 2005.

Although MCA was best known as a technologist and as an inventor of laser structures, he was also an accomplished theoretician. He had a broad knowledge of mathematics, both pure and applied, and in addition he was very skilful in combining analytical and numerical methods. Some examples will be described.

Also in his second career as a university professor, MCA was driven by the motivation to turn research results into practical applications. Over the past 20 years his goal has been to develop lasers for the infrared spectral range. He and his group were able to realize lasers with emission wavelengths ranging from 1 to 250 μm on the basis of sophisticated material research and various physical concepts.

Around the turn of the millennium, he developed the concept of the buried tunnel contact, which made it possible to produce surface-emitting lasers (VCSELs) in the InP material system. With emission wavelengths of 1.3 to 2.3 μm, these devices find application in high-speed data transmission as well as in absorption spectroscopy (TDLAS) for the detection of gases. The spin-off company *VERTILAS*, which he co-founded and accompanied as a scientific adviser over the years was a result of this research.

For longer wavelengths, antimony-containing compounds are the materials of choice, but this has required the development of a completely new technology. In combination with a new design of the active region based on type-II heterostructures, electrically pumped VCSELs with emission wavelengths up to 4 μm could be fabricated.

With quantum cascade lasers, light can be generated at even longer wavelengths (roughly 6 to 12 μm). At the beginning of the 2000s, this type of laser was also realized in his working group. Due to the monolithic integration of two lasers with different wavelengths and corresponding grating structures, it was possible to produce emitters in the wavelength range from 4 to 250 μm by utilizing the Second Harmonic Generation or the Difference Frequency Generation.

Two more of his PhD students working in his research group at that time used their experience in the field of material fabrication and manufacturing of quantum cascade lasers to set up their own spin-off company, the company *BROLIS Semiconductors* in 2012.

The work of MCA has been, and is still, widely cited. In total, he has (co-)authored more than 500 publications that have been cited about 6,000 times and achieved an *h*-index of 37.

We have been privileged to have Markus-Christian Amann as a colleague and as a friend. All honour to his memory.