buffer layers before ZnSe deposition. The scarcity of good quality ZnSe substrates severely limits the impact of the homoepitaxy route.

Related to the laser lifetime is the performance of the ZnTe-ZnSe heterojunction contacts. Although, these contacts do not limit the lifetime of today's research lasers, they will have to further improve if they are to satisfy the lifetime demands placed on commercial devices.

Decreasing the wavelength into the blue spectral region below 480 nm involves the elimination of Cd in the quantum well together with the growth and p-type doping of $Zn_{1-x}Mg_xS_ySe_{1-y}$ having a band gap greater than 3 eV (x and y around 0.20). Some studies have shown that the doping efficiency drastically reduces as the band gap increases above this value. So further research is needed to ascertain if this reduction is intrinsic to the material or if it is affected by the present state-of-the-art in MBE growth technology. The smallest wavelength achieved so far with a ZnSe-based laser is 468 nm [6].

Since the demonstration of the first ZnSe laser, MBE has remained the growth technology of choice. Metalorganic chemical vapour deposition (MOCVD), the other commonly used epitaxial technology for optoelectronic devices, has failed so far to deliver reproducible p-type doping of ZnSe. The problem is that nitrogen acceptors are passivated by hydrogen atoms, the unwanted by-products of the conventional MOCVD process. Alternative chemical sources for the growth by MOCVD of ZnSe are being actively sought in order to overcome passivation by hydrogen.

One can conclude that steady progress has characterized the development of the ZnSe semiconductor laser. Many elements of the road map towards a reliable technology have been identified. Some of them are of a fundamental nature, such as the doping of wide band gap semiconductors to obtain laser devices that emit in the blue. Others, such as the role of defects in degrading the light output, recall similar challenges confronted in the past while developing today's conventional GaAs and InP lasers. It is expected that with improved contacts, further reductions in defect density, and refinements in device processing, the cw lifetime and other performance parameters of ZnSe lasers will keep evolving towards commercially acceptable levels.

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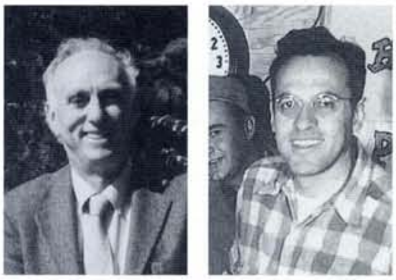
1995 NOBEL PRIZE IN PHYSICS

Opening and Closing Families

The 1995 Nobel Prize in Physics has been awarded to **Martin L. Perl,** Stanford University, CA, USA, for the discovery of the tau lepton and to **Frederick Reines**, University of Califormia-Irvine, CA, USA, for the detection of the neutrino.



M.L. Perl (left) in 1987 and F. Reines in 1953.

In today's language, the discovery of the neutrino closed the first family of quarks and leptons whereas the discovery of the tau lepton opened unexpectedly the third family of fundamental particles (which was closed recently with the discovery of the top quark).

The discovery of the tau takes us back 20 years back to the Stanford Linear Accelerator Center (SLAC), where the 80 m in diameter electron-positron collider ring SPEAR (see figure) was opening up a new range of energy - enough, as it turned out, to produce a tau together with its antiparticle. The tau is about 3500 times heavier than the electron, its cousin in the first family, and about 1.7 times heavier than the muon, its cousin in the second family. Each charged lepton is associated with a specific neutrino, which is massless at the precision of present-day measurements. CERN's Large Electron-Positron collider has confirmed the existence of three, and only three, neutrinos and the three related families represent the building blocks of Nature as we know it today.

The discovery of the tau was not an easy matter. There was no idea at the time whether such a particle existed and, of course, nothing was known about the most promising mass range to probe. Previous searches for a new lepton (why not one more since the muon was there together with the electron ?) had been negative. One could simply search with determination, an open mind and a liking for the unexpected — qualities which Martin Perl exemplified.

The signature of the tau is offered by the production of a tau-antitau pair in electron-positron annihilation. The tau may decay into an electron together with its antineutrino and a tau neutrino, while the antitau can give an antimuon together with its neutrino and a tau neutrino. The simultaneous appearance of an electron and an antimuon signals something *a priori* very special. The neutrinos are, however, undetectable and only the overall energy balance shows an apparent deficiency which is associated with their presence. The signature is thus clear, but hard to establish with certainty. After the first announcement, it still took a great experimental effort by the SLAC team to generate convincing evidence for the existence of the tau.

The tau not only heralded the appearance of the third family with its b and t quarks but also became a very powerful tool in particle physics. Its production and decay (an analyzer of its polarization) provide, in particular, precious information about spin effects.

With the discovery of the neutrino we go back 40 years. The neutrino had been postulated by Pauli in 1930 in order to solve the problem of energy conservation in β-decay. It was shortly after incorporated by Fermi in his theory of β-decay. There was very soon no doubt that the neutrino existed, but it was realized that the low-energy neutrinos of β-decay had mean-free paths in matter that were measured in light years! So the neutrino seemed to be unobservable. But, as Pauli said in 1956: *"The extraordinary technical difficulties of the experimental demonstration of this reaction* (the capture of a neutrino) *were finally overcome by Cowan and Reines".* Clyde L. Cowan has since died, and Reines is now acknowledged for a major experimental achievement.

The Reines-Cowan experiment used a very powerful nuclear reactor as an intense source of (anti)neutrinos. There detector was a barrel filled with about half a cubic metre of water containing cadmium chloride and placed between liquid scintillation detectors (see figure). Neutrinos could thus be captured in an unambiguous way. The antineutrino hits a proton which turns into a neutron with the production of a positron. The positron annihilates against an electron with the production of specific γ-rays which are detected. The capture of the neutron in cadmium also yields γ-rays. Detected about a microsecond later, they give a delayed coincidence signal to provide the signature.

They were long struggles with a low signal and a large background. But the neutrino was finally identified as a *bona fide* particle and it has since become a very powerful tool in particle physics. Its mean free path in matter decreases strongly with energy so high-energy neutrinos, produced with an intense flux from an accelerator, have become very powerful probes for studying the quark structure of matter. Neutrino scattering experiments also provided the first experimental evidence for the electroweak theory of particle physics with the discovery of the "neutral current" interaction. Neutrinos allow us to "see" inside the sun and play prominent roles in flares from supernovae and in our description of the Big Bang. So they have much to do with the structure of the cosmos at large. There remain today fascinating questions associated with the neutrino mass and with possible transformations between the three different neutrino species.

M. Jacob, *CERN, Geneva*