Laser diode with polarization doping

Semiconductors were discovered or perhaps invented as a group of materials whose electrical conductivity can be quite easily manipulated. The same semiconductor can be a good insulator or have mobile positive or negative charges. This is achieved by precisely adding a small number of impurities (atoms of different element) to the crystal lattice of a semiconductor. If only one in one hundred thousand atoms of gallium, in gallium arsenide compound, is replaced with silicon, this material will conduct electricity very well, and the mobile charges will be electrons. If, for example, zinc is doped instead of silicon, the resulting conductivity will be the so-called hole conductivity. Thanks to the possibility of the coexistence of two types of carriers in semiconductors, we are able to build components of modern electronics, diodes, transistors, LEDs and laser diodes. Even in the 70s of the last century, semiconductors were called materials with the narrow energy gap, primary silicon, germanium, then also gallium arsenide. The energy gap is the energy that divides the filled electronic levels from the empty ones in a semiconductor. The energy of the photons emitted by the material depends on the size of this energy gap. It turned out, however, that semiconductors with a wide energy gap, emitting light in the visible and UV range, most often have high resistance, and they rather tend to become insulators. Sometimes it is relatively easy to dope them for a given type of conductivity (mostly electron-type conductivity), but it is exceptional to control both types of conductivity at the same time. The most popular wide-gap semiconductor materials belong to InAlGaN nitride family. Within this group of compounds, the energy gap ranges from 1.7 to 6.2 eV. The researchers and engineers solved the problem of doping of these materials (Nobel Prize 2014) at least to certain extent. Thanks to their achievements we can use multicolor and white LEDs, enjoy modern TV sets with nitride LED backlighting, or play on Sony Play Station which uses nitride violet lasers for information reading. But is it possible to further improve devices based on these semiconductors, despite the fact that nature resists so clearly? It turns out that yes! Semiconductor nitrides have lower symmetry of their crystal lattice than ordinary semiconductors and consequently have a built-in dielectric polarization. If we now grow a layer of aluminum gallium nitride - AlGaN with a variable chemical composition, then such a layer can suddenly start conducting current without doping, and additionally depending on the way we grade Al content of the layer we can create electron or hole conductivity. Epitaxial growth provides us a tool for such a composition engineering of thin semiconductor layers. The layers in which, instead of introducing foreign atoms, we control the profile of the chemical composition are called layers with polarization doping. What polarization doping can bring: first of all, devices with greater efficiency in converting current into light, with a longer life, and also those that can work at low temperatures. Nitride lasers are at the heart of the new generation optical atomic clocks currently under development. Maybe thanks to polarization doping it will be easier to send them into space one day? The proposed project is to determine how much the technology of polarization doping can help us today to make better, more energy-efficient and more functional light emitters.