SAW-driven light-emitting lateral *n-i-p* devices

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Abstract

We present a surface-acoustic-wave (SAW) driven light-emitting junction that can realise a single-photon-source for quantum cryptography applications. Our lateral n-i-p junction is realised starting from an undoped GaAs/AlGaAs quantum well by gating and incorporates interdigitated transducers for SAW generation and lateral gates for current control. We demonstrate acoustoelectric transport and SAW-driven electroluminescence. The acoustoelectric current can be controlled down to complete pinch-off by means of the lateral gates. Devices development will lead to the SAW-based single photon source.

Introduction and motivations

Quantum information has opened the way to a completely new approach toward secure information sharing. Up to now quantum-cryptography protocols have not yet achieved large-scale diffusion, mainly owing to the lack of fast and reliable single-photon sources and detectors. In this context Foden *et al.* proposed [1] a single-photon emitter exploiting single, radiative electron-hole recombinations in a lateral *n-i-p* device promising GHz photon-emission rate. Electrons are driven from the *n* to the *p* part of the device using the charge transport induced by surface acoustic waves (SAWs)[2,3]. This approach allows taking advantage from the possibility to quantize current to the limit of single electron per SAW period [4] by means of a quantum point contact (QPC) hosted in the intrinsic region between the *n* and the *p* sections of the device.

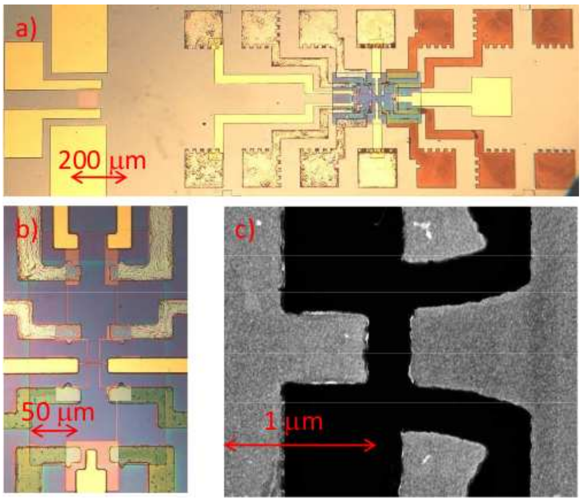

Figure 1: a) and b): Optical images of a n-i-p device. n and p Ohmic contacts, IDT, insulating layer and gates are shown. c): SEM image of the QPC region.

Devices description

Here we demonstrate for the first time a light-emitting, gate tunable, *n-i-p* lateral device compatible with SAW-driven transport. Our fabrication scheme is the main building block for the proposed SAW-driven single-photon-source for quantum cryptography applications. Our devices are based on undoped GaAs/AlGaAs heterostructures containing a quantum well (QW). Annealed *n-* and *p*-type Ohmic contacts (OCs) are fabricated to locally provide donors and acceptors.

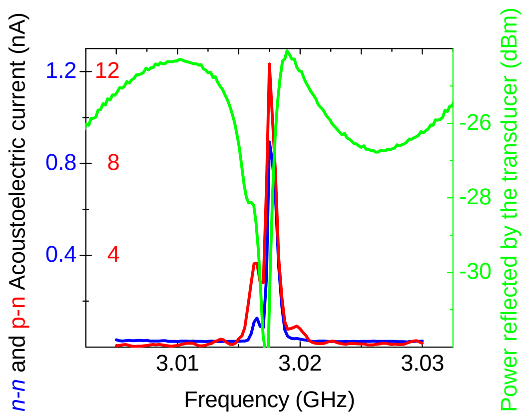

Figure 2: Comparison between the frequency characterisation of the IDT (green line) and the current between two n-type Ohmic contact (blue line) and across the junction (red line). A peak is observed at the IDT resonance frequency.

Electrons and holes are induced in the QW by means of metallic gates that partially overlap the OCs. Insulation between OCs and gates is provided by a dielectric layer deposited before gate evaporation. The geometry of the OCs and the gates was optimised in order to allow the SAW-driven transport, to host a QPC between the *n* and the *p* part of the device, and to allow the detection of the emitted light.

Our devices incorporate an interdigital transducer (IDT) to generate SAWs propagating from the *n* to the *p* side of the device.

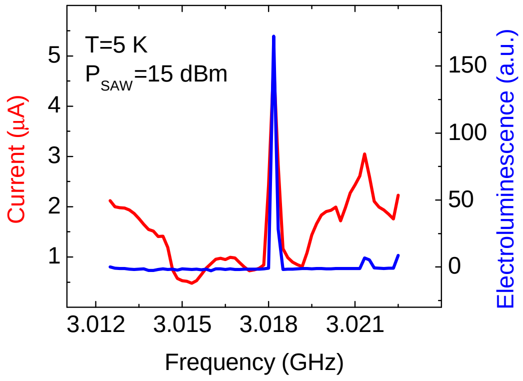

Figure 3: Comparison between the current across the junction (red line) and the electroluminescence (blue line) measured by means of a CCD as a function of the frequency of the excitation signal applied to the IDT.

Main achievements

Our results demonstrate that it is possible to induce an electron gas adjacent to a hole gas in an undoped QW realising a lateral p-i-n junction. Driving the junction above threshold leads to electroluminescence due to electron-hole recombination in the QW. Additionally we demonstrate acoustoelectric transport across the junction (See Fig. 2): at the IDT resonance frequency a peak is observed in the current between two *n*-type OCs aligned along the SAW direction and in the current across the junction. In this condition SAW-driven electroluminescence is observed (see Fig. 3). Furthermore, we show that the QPC is able to modulate the charge transfer across the junction down to complete pinch-off.

Conclusions

In conclusion we demonstrated a SAW-driven and light-emitting device which constitutes a very important step toward the SAW-driven single-photon emitter.

References

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