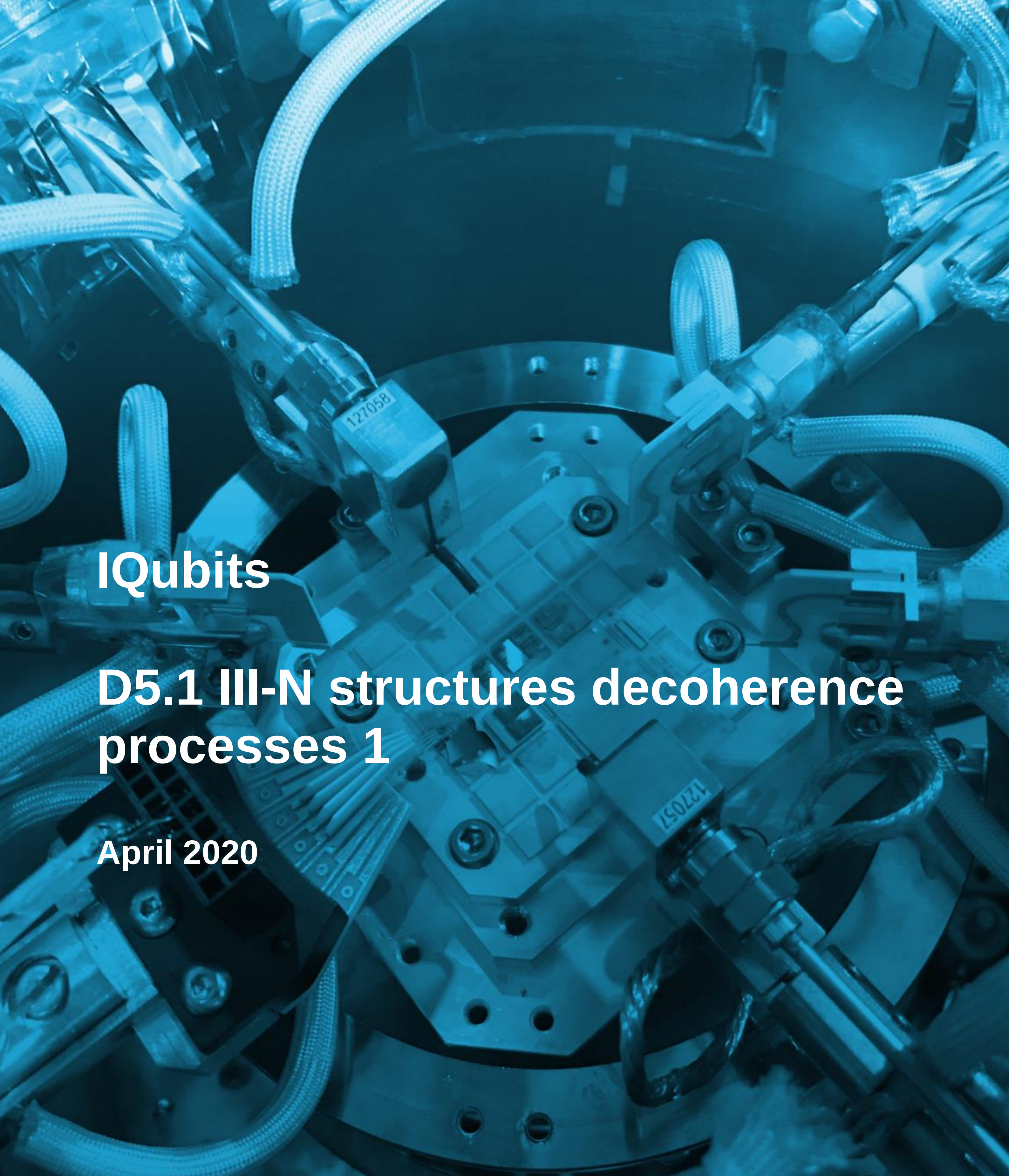

IQubits

D5.1 III-N structures decoherence processes 1

April 2020

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Contact information

PROJECT COORDINATOR

info@iqubits.eu
+459350851

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Project Title	**Integrated Qubits Towards Future High-Temperature Silicon Quantum Computing Hardware Technologies**
Acronym	**IQubits**
Grant Agreement N.	**829005**
Partners	**Aarhus University (AU)** **Consiglio Nazionale delle Ricerche (CNR)** **University of Toronto (UofT)** **Foundation for Research and Technology Hellas (FORTH)** **National Institute for Microtechnologies (IMT)** **Applied Materials (AMat)**
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0.2	09-06-2020	Draft Version 2	E. Ilipoulos; G. Konstantinidis (FORTH)
0.3	12-06-2020	Draft Version 3	D. Zito (AU)
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0.5	16-06-2020	Draft Version 5	D. Zito (AU)
1.0	17-06-2020	Final Version	D. Zito (AU)

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DISCLAIMER

This project has been co-funded by the European Union's Horizon 2020 Research and Innovation Programme through the FET Open project IQubits under Grant Agreement N. 829005.

1 EXECUTIVE SUMMARY

This document reports on the first-year efforts to establish the hardware required to assess the decoherence processes in the III-nitride structures to be developed and characterized within IQubits.

In particular, this deliverable describes the time-resolved Kerr rotation (TRKR) hardware setup for measurement III-N hetero(nano)structures to be developed by FORTH, with reference to the description of work reported in Part B. The working mechanism of TRKR is described and, as a part of the experimental setup, a femtosecond UV laser source has been implemented and it is about to be completed.

The TRKR will be used in measurements of spin decoherence in low-density two-dimensional electron gas (2DEG) and hole gas (2DHG) III-Nitride structures.

2 TIME-RESOLVED KERR ROTATION (TRKR) SETUP FOR STUDY OF SPIN DECOHERENCE MECHANISMS AND TIMES

The spin decoherence process mechanisms in the case of III-Nitride materials and heterostructures (like 2DEG structures) are largely unknown. Neither the nature of spin-orbit coupling (Rashba and Dresselhaus contributions) nor the spin decoherence times T_1 and the underlining mechanisms have been studied in a systematic and comprehensive manner. There are very few reports [1-4] concerning such measurements in III-N, while knowledge of relevant parameters and systematic study of their dependence on temperature, carrier densities and crystal orientation are of importance in order to effectively design future III-N heterostructures for spin qubits applications. Thus, in the course of the IQubits project, a dedicated experimental set-up to systematically study and measure decoherence times and mechanisms is planned to be carried out by FORTH.

The experimental setup is based on time-resolved Kerr rotation (TRKR) measurements and is schematically described in Fig. 1. The specimens under investigation will be put inside a superconductive magnet cryostat (capable of 1.6-300K and 0-7T operation) with optical access (Oxford SpectroMagPT). The experiment is of a pump-probe type to follow the time evolution of carrier spin coherence. Thus, a circularly polarized pump beam, derived from a femtosecond laser UV output band incident on the sample creates a spin polarized excited carrier collection. The spin evolution is tracked through the measurement of the Kerr-rotation of a linearly polarized probe beam (also derived from the femtosecond UV pulse) incident on the specimen at a different angle. By mechanically controlling the time delay between pump and probe it is possible to study the time evolution of spin decoherence. For enhanced sensitivity, the rotation will be measured by employing a quarter wave plate (QWP) and a Woolaston prism in order to split the reflected beam into two components with orthogonal polarizations and detection of them using a balanced differential photodiode scheme. For enhanced signal-to-noise ratio, the helicity of the pump beam will be modulated using a photoelastic modulator and the output of the diodes differential amplifier will be synchronously detected by using a lock-in amplifier. A possible future upgrade of the setup will be the use of an optical parametric amplifier (OPA) to change the central wavelength of the femtosecond probe beam.

In the development of this setup, we have faced two major problems: (i) The available cryostat presented problems in operation and was not possible to reach the base temperature necessary for the superconductive magnet operation. (ii) The available femtosecond laser source, located in a different room, could not be interfaced with the cryostat due to the large spatial distance (> 15 m). Both problems have been addressed. The cryostat was repaired and reinstalled. Correct operation has been verified.

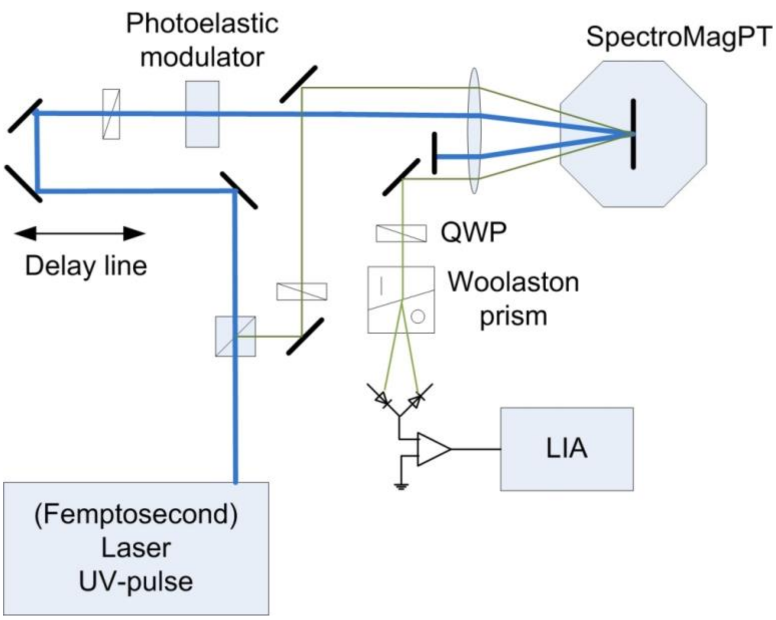
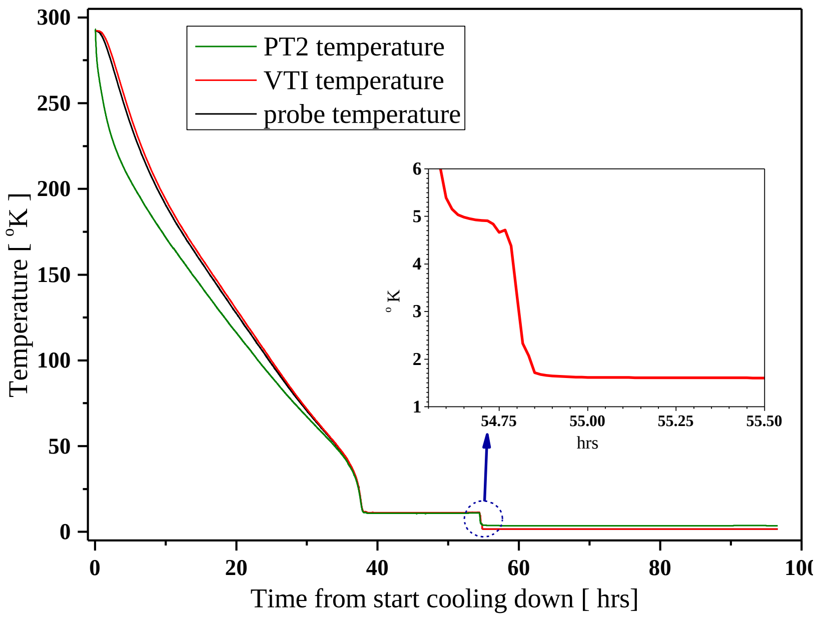


Fig. 1: Schematic depiction of the TRKR setup.

Fig. 2(b) shows the collected temperature monitor data of the verification cool down run on January 2020. This shows that stable operation at 1.55 K base temperature is reached.

(a)



(b)

Fig. 2: (a) Photo of the reinstalled SpectromagPT cryostat at FORTH. (b) Verification cool-down run temperature data confirming successful cool-down and stable base temperature of 1.55 K.

Concerning the UV femtosecond laser source, in support of the IQubits work plan, FORTH decided to source available parts and know-how from the Attosecond Science Research division, to help set-up a dedicated laser source. An in-house built 266nm center wavelength, ~200fs pulsed with ~0.5 mJ per pulse laser source, is in the late stages of assembly. The optical layout of the Ti:S system, based on the well-known Chirp Pulse amplification (CIA) approach is depicted in Fig. 3. Photos of the source setup (oscillator, stretcher and regenerator) are shown in Fig. 4. The compressor part is under development and will soon be integrated with the other parts. After imminent completion and pre-testing, the source is to be transferred close to the SpectromagPT cryostat for fine-tuning and integration with the entire TRKR set up. Final assembly of the total experiment instrumentation expected in the fall of 2020.

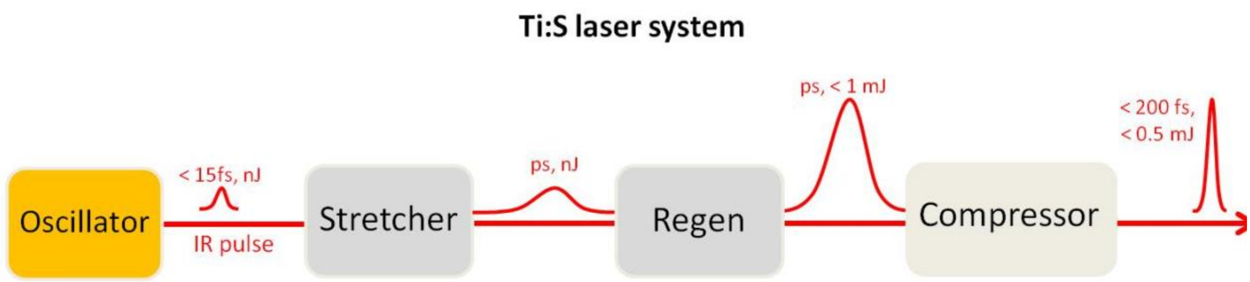


Fig. 3: Optical layout of the femtosecond UV laser source.

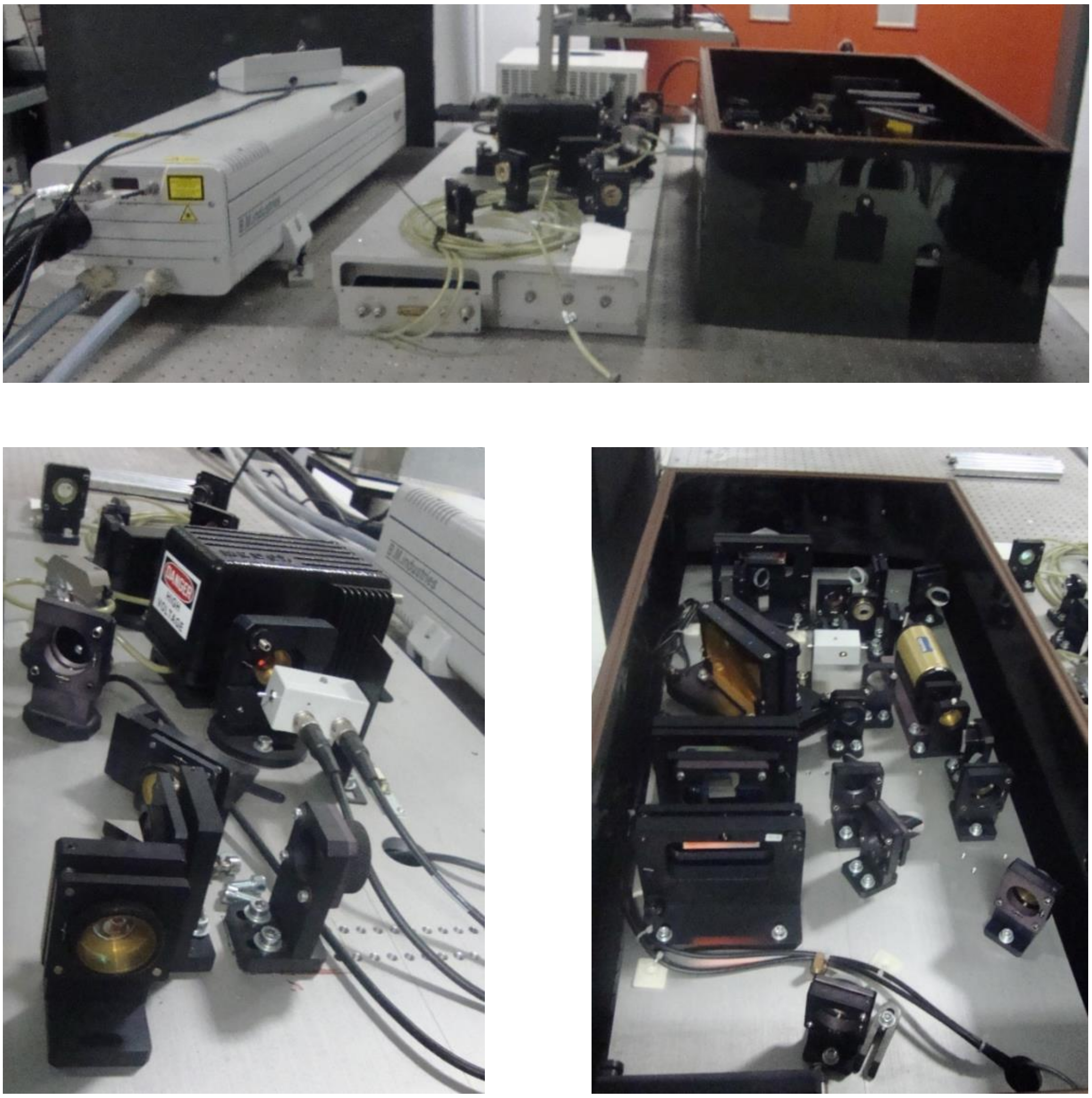


Fig. 4: Setup of in-house built 266nm 200fs high power laser source for integration in the relevant TRKR setup at the Institute of Electronic Structure and Laser (IESL) of FORTH. Top: overall picture of the assembled parts. Bottom left: the “stretcher” assembly. Bottom right: the “regenerator” assembly.

3 REFERENCES

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