s-Nebula : Novel Spin-Based Building Blocks for Advanced TeraHertz Applications

Document Title	Data Management Plan		
Document type **Due date**	Deliverable D5.1 June 30, 2020	**Author** **Dissemination level**	Dr Romain Lebrun Public
Project	s-Nebula	**Grant number**	863155
Coordinator	THALES	**Project coordinator**	Dr Romain Lebrun
Call identifier **Work Package**	H2020-ICT-2019-2020 WP5: Project Management (PM)		
Project Start date **Project Duration**	01/01/2020 42 months		

Beneficiaries list

No	Name	Short name	Country
1	THALES SA	THALES	France
2	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	CNRS	France
3	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	Fraunhofer	Germany
4	JOHANNES GUTENBERG-UNIVERSITAT MAINZ	JGU	Germany
5	FREIE UNIVERSITAET BERLIN	FUB	Germany
6	VYSOKA SKOLA BANSKA - TECHNICKA UNIVERZITA OSTRAVA	VSB	Czech Republic
7	UPPSALA UNIVERSITET	UU	Sweden

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Novel Spin-Based Building Blocks for Advanced TeraHertz Applications

Project abstract:
s-NEBULA explores and develops a revolutionary approach to TeraHertz (THz) technology, both for generation and detection of THz radiation, initiating the new field of spin-based TeraHertz (s-THz) technology, a game changer for the future of THz field. The ambition of s-NEBULA is to provide a platform of room-temperature innovative spin- based THz building blocks, arising from novel combinations of magnetism and optics. s-NEBULA will provide cutting-edge solutions to solve bottleneck scientific issues in the THz field motivated by clear needs in judiciously chosen target applications. These include variable-baseline broadband pulsed emitters and voltage-controlled compact detectors for non-destructive testing (NDT), intrinsically-modulated CW emitters for THz communication and polarization-programmable emitters for ellipsometry. We will demonstrate innovative schemes for THz emission using spin-orbit interfaces targeting optically driven s-THz pulsed emitters with bandwidth > 20 THz, with enormous potential for NDT applications. For THz communication, data traffic densities of several Tbps/km2 are predicted for 5G networks, but not a single THz data link beyond2 THz s-NEBULA will develop high-power tunable CW emitters working beyond 5 THz. Besides, we will investigate a disruptive approach combining antiferromagnetic materials with direct voltage rectification effects, targeting a tunable & compact detector, key element for on-chip THz systems of tomorrow. Furthermore, combining THz radiation with magnetism enables an extra lever to control the emitted wave; intrinsic modulation/demodulation becomes possible, as well as polarization control for innovative schemes in ellipsometry. All these approaches are not possible with existing THz technologies. The consortium gathers leading European expertise in significantly diverse areas (optics, magnetism, materials preparation, advanced theory, industrial integration, THz metrology) that will enable multi-disciplinary work.

1. DATA SUMMARY

Purpose of data collection and relation to the objectives. The project will generate data as an integral part of structural, optical and electrical characterization of thin film materials grown by different methodologies. This characterization is critical to achieve the following project objectives as described in the GA

- A pulsed broadband (> 20 THz) and a tunable CW (> 4 THz) emitter
- A fully operative spin-based THz detection mechanism
- Ultrafast (> 50 GHz) modulation of both optically and electrically -driven THz emitters, achieving at least 10 GHz modulation rate with a modulation index of better than 50% at 2.5 THz
- Polarization control with a cross-polarization rejection > 20 dB for broadband radiation
- A unified approach describing spin transport, THz generation and propagation in complex structures

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The data will provide useful information about the following items which are ultimately related to the above objectives :

	DATA TYPE	MEANS OF PRODUCTION	FORMAT
1	**Magneto-transport measurement**	Output from instrument	ASCII, TXT
2	**Optical measurement (THz spectroscopy, ellipsometry**	Output from instrument	ASCII, TXT
3	**Structural characterization**	Output from instrument	ASCII, TXT, PDF
4	**Simulations**	Computer simulations	ASCII, TIF, PDF

Table 1*: The measurements which are the source of the produced data, the information which is extracted and the objectives to which the data are related*

Data format and size:
In addition to the raw/uncorrected data, converted and corrected data (in engineering units), as well as several other forms of derived data will be produced.

Metadata that describe the experiments with their materials, experimental environment and structural or measurement parameters will be produced.

The raw data formats are expected to be plain text, ASCII (.txt) and the corrected/derived data formats will be PDF (.pdf) or TIFF 6.0 uncompressed (.tif).

The expected size of data is not known, but a total storage demand of 2 GB per partner for the three years of the project is estimated. The data will be stored in each partner institute and the publication data will be shared among the s-Nebula partners and via a Zenodo repository.

Target groups
The project is expected to re-use only experimental data originated/collected by each participating partner in past experiments.

The data will be of interest to the research and technological community in the area of new optics, magnetic materials, and spintronics. The interested researchers are expected to be from the following disciplines: Materials science and engineering, physics, electrical engineering, nanotechnology, equipment manufacturing.

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2. FAIR DATA

2.1 DATA RESPONSABILITY

- Every partner will be technically and legally responsible for keeping, disseminating and preserving data created within their labs, even in cases where works are led by researchers coming from various partners.
- Results are owned by the beneficiary that generates them. Two or more beneficiaries own results jointly generated under the terms stated in article 26.2 of the Grant agreement.
- The Research Executive Agency (referred as 'the Agency') may -with the consent of the beneficiary concerned- assume ownership of results to protect them up to four years after the 1st January 2020 under the terms stated in article 26.4 of the Grant agreement.
- Each beneficiary must examine the possibility of protecting its results and must adequately protect them under the terms stated in article 27 of the Grant agreement.
- Each beneficiary must up to four years after the 1st of January 2020 take measures aiming to ensure exploitation of its results under the terms stated in article 28 of the Grant agreement.
- Unless it goes against their legitimate interests, each beneficiary must take measures as soon as possible to disseminate its results under the terms stated in article 29 of the Grant agreement.

Intellectual property bindings are to be found in the s-Nebula consortium agreement. At the project level, the Coordination Team will be a technical help to partners putting their data and publications on open access platforms.

2.2 MAKING DATA OPEN-ACCESS FINDABLE, INCLUDING PROVISIONS FOR METADATA:

Data produced within the s-Nebula frame must be accessible up to four years after the beginning of the project. As stated in the Grant agreement number 863155, the following types of data will be published online in open access, directly on the website https://zenodo.org/communities/s-nebula/?page=1&size=20. These data will be digitally connected to the s-Nebula project. A link to the repository will also be accessible through the project website: http://s-nebula.eu.

Such data are:

- Magnetic, electronic and structural properties in magnetic heterostructures,
- Optical and magneto-transport characterization of multilayers and patterned devices.

Data linked to openaccess publications must therefore be annotated by metadata. Good metadata is the key for research data access and re-use. The following website provides information about disciplinary metadata standards: http://www.dcc.ac.uk/resources/metadata-standards
Furthermore, the website http://gwyddion.net/ provides a number of freeware programs available to analyse data in physics.

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2.3 MAKING PUBLICATIONS OPENLY ACCESSIBLE:

Partners will be following the process explained below. The lead partner of the publication takes responsibility for the open-access process for peer-reviewed publications.

a. *Publication in the journal of their choice*
   Partners must be keeping in mind that the Agency asks projects not to accept more than 6 month embargo (to check the publishers' policies use http://www.sherpa.ac.uk/romeo/)

b. *Give open-access to all peer-reviewed publications, with a maximum of 6 months embargo.*
   i. Partners upload publications on http://arxiv.org/, or on another openaccess platform of their choice,
   ii. The lead partner of a publication will publish the data linked to publications on https://zenodo.org/communities/s-nebula/?page=1&size=20. Thanks to the publications' DOIs, the data will be linked to publications,
   iii. Update the publication lists of s-Nebula publications on the project website,

c. *Openaire*

Once publications are published on arxiv and their data published on Zenodo, the OpenAire website will do the linkage between them. All s-Nebula published work will be present on this webpage: https://explore.openaire.eu/search/project?projectId=corda__h2020::fe1087364622a7eee862f1431f86a675
In order for publications and data to appear on this website, one must state when completing forms on the arXiv and Zenodo websites that the concerned work is being financed by Horizon 2020 project number 863155.

2.4 MAKING DATA INTEROPERABLE:

In order to make the data accessible from others the file upoaded will be mainly in ASCII format which facilitates the interoperability of the data. The metadata files will give all the information needed by others to access the data. Also, Zenodo uses JSON Schema as internal representation of metadata and offers export to other popular formats such as Dublin Core or MARCXML.

Data generated by s-Nebula project are very specific and specialized in nanoscience, optics and nanotechnology. The vocabulary used in nanoscience is standard.

2.5 INCREASE DATA RE-USE (THROUGH CLARIFYING LICENSES):

The open access data will be the ones which will be characterized as non-confidential following the procedures in Fig.1. Therefore, the data will be free for use by others without licensing.

The data will be made available for re-use once they are posted in Zenodo. There will be no embargo period.

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The data posted to Zenodo will be available for use by third parties after the project end. We can guarantee a reuse for a period of 4 years after the project end.

Each partner will be responsible to make accessible the data of their publications. The quality of the data will be monitored by the coordinator and the WPs leaders. They will make sure that the data can be opened and plotted in good order and that they contain the promised information. It is expected that this screening process assures the quality of the data.

3. DATA SECURITY

Materials to be publicly shared will be stored with the Zenodo repository, a service that provides deposit access and preservation services. Deposited items (published records) will be assigned a unique DOI on Zenodo. Zenodo offers high-level preservation, security, and compatibility for data stored in a variety of standard file formats, and assures high visibility in most commonly used search engines.

4. ETHICAL ASPECTS

There are no ethical aspects in the project

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