**Deliverable 9.2**

**WP9 Final Report (period 01/01/2021-31/12/2022):**

**Hybrid Integration and Packaged Solutions for Comb Generator Modules**

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Project start date: January 2019

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| **0.1** | 27/06/2022 | Joanna Łucyszyn | First draft - circulated internally to beneficiaries involved in tasks |
| **0.2** |  | Final draft circulated to the Consortium, including WP Leaders, for feedback |
| **1.0** |  | Final version with the Consortium’s input |

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4. Universiteit Gent (UGent)
5. Universitat Politecnica de Valencia (UPV)
6. Karlsruher Insitute Fuer Technologie (KIT)
7. Menlo Systems GmbH (MENLO)
8. Max-Planck-Gesellschaft Zur Feorderung De Wissenschaften EV (MPQ) (Institute for Quantum Optics) & (Institute for the Science of Light)
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# **Work package summary**

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| **MICROCOMB WP9 Report**Work package title: ***Hybrid integration and packaged solutions for comb generator modules*** |
| **Participation partner** | **Principal Investigator** | **ESR number according to the GA**[**ESR numbering explained**](https://www.microcomb-eu.org/esr-numbering) |
| 1 – BATH | D.Skryabin | ESR N°1 – Mr Zhiwei FanESR N°2 - Mr Vladislav Pankratov; |
| 5 – UGENT | B.Kuyken | ESR N° 7 – Mr Ewoud Vissers |
| 6 – UPV | P.Munoz | ESR N°8 – Mr Louw Roel van der Zon |
| 7 – KIT | C.Koos | ESR N°9 – Mr Innokentiy ZhdanovESR N° 10 – Mr Yung Chen;  |
| 8 – MENLO | R.Holzwarth & K.Stockwald | ESR N°11 – Mr Ignacio Baldoni |
| **Lead Beneficiary** | 5 – UGent/ B.Kuyken |

The outside-laboratory applications of frequency combs require the development of packaged solutions. Traditional high-power light sources that pump a microresonator are relatively bulky and difficult to operate. Hence, a packaged customer ready device is required, and appropriate techniques need to be developed. In this workpackage we will develop first such devices using microcombs for astro and optical data processing applications using building blocks developed in other WPs. Here, they will rely on so called photonic wire bonds to connect the different components. A more advanced solution to the problem is to use chip-scale light sources integrated on the same chip with a microresonator. Therefore, important objectives of this work package are to develop a device that is an electrically powered turn-key system with a single fiber output. This approach relies on the heterogeneously integrated mode-locked lasers that have III/V gain sections, amplifiers, saturable absorbers that are all electrically pumped on a single silicon chip. Having a transportable frequency comb generator would allow to increase the exposure of microcombs. Since the performance of the sources as well as their robustness is key for this, we will test them in as standalone devices in the labs of MENLO. This research WP is linked to the intensive courses 2, 6 in WP 5 and it comprises activities of the associated ESRs as outlined in the tasks listed below. Technical details of the tasks can be found in the descriptions of the various ESR projects.

# **Partner progress on tasks in Work Package 9**

|  |  |  |
| --- | --- | --- |
| ***Milestones*** | ***Milestone title*** | ***Means of verification*** |
| ***MS3*** ***(BATH)*** | *ESRs 1 & 2 have numerical codes for modelling of comb solitons and comb generation in the experimental schemes developed by consortium* | *ESRs 1,2 have numerical codes for modelling of comb solitons and comb generation in the experimental schemes developed by consortium* |
| ***MS 7*** ***(UPV)*** | *Operational proof of concept SiN spectrometer chips* | *operational proof of concept SiN spectrometer chips* |
| ***MS10 (MENLO)*** | *Operational and characterised microring resonator for generation of a visible, broadband and flat spectrum with mode spacing > 10GHz suitable for integration into AstroComb module; design of the module* | *Operational and characterised microring resonator for generation of a visible, broadband and flat spectrum with mode spacing > 10GHz suitable for integration into AstroComb module; design of the module* |
| ***MS12*** ***(UGENT)*** | *hybrid integration of III/V source and comb generators on SiN platform for dualcomb spectroscopy* | *hybrid integration of III/V source and comb generators on SiN platform for dualcomb spectroscopy* |

## **Task 9.1 Hybrid integration of III/V source and comb generators on SiN platform and demonstration of the low RF noise properties**

**Beneficiaries and partners involved in the task: ESR 7 (GENT)**

Objectives of this tasks are to demonstrate low noise RF signals and dual-comb spectroscopy using on-chip microcomb generators with integrated III/V-on-silicon sources.

[***Milestones met***](#_Partner_progress_on)***:***

Publications:

*
*

Please complete this [Dissemination and communication spreadsheet](https://drive.google.com/drive/folders/1olgxot8mwzAmIHA6vsDjBbLBKZyKNzqg?usp=sharing) for your individual project.

Please complete the [secondments google sheet](https://docs.google.com/spreadsheets/d/1-eNy0gbfJLk2rj-iqzO2CyLso6uCpvEb/edit#gid=1369407323) and if the secondment didn’t take place please provide the justification in the column “L”.

## **Task 9.2 Hybrid integration on SiN platform of the comb sources for dual-comb spectroscopy**

**Beneficiaries and partners involved in the task: ESR 7 (GENT)**

Objectives for this task are to develop a numerical model for a comb generator with an integrated laser source.

[***Milestones met***](#_Partner_progress_on)***:***

Publications:

*
*

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## **Task 9.3 Demonstration of packaged comb generator modules with integrated pump sources and amplifiers for optical data processing**

**Beneficiaries and partners involved in the task: ESR 10 (KIT); ESR 8 (UPV); ESR 11 (MENLO); VLC; LGT**

Objectives for this task are to demonstrate packaged microcomb devices with conventional sources for data processing and astro applications.

**ESR 8 (UPV):**

**ESR 11 (MENLO):**

**ESR 10 (KIT):**

[***Milestones met***](#_Partner_progress_on)***:***

Publications:

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Please complete this [Dissemination and communication spreadsheet](https://drive.google.com/drive/folders/1olgxot8mwzAmIHA6vsDjBbLBKZyKNzqg?usp=sharing) for your individual project.

Please complete the [secondments google sheet](https://docs.google.com/spreadsheets/d/1-eNy0gbfJLk2rj-iqzO2CyLso6uCpvEb/edit#gid=1369407323) and if the secondment didn’t take place please provide the justification in the column “L”.

## **Task 9.4 Modelling comb generation with an integrated laser source**

**Beneficiaries and partners involved in the task: ESR 1 (BATH), ESR 7 (GENT), LUCEDA**

**ESR 1 (BATH):**

**ESR 7 (GENT):**

[***Milestones met***](#_Partner_progress_on)***:***

Publications:

*
*

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## **Task 9.5 design of a fully packaged microcomb system for high precision spectroscopy in astronomy**

**Beneficiaries and partners involved in the task: ESR 11 (MENLO)**

[***Milestones met***](#_Partner_progress_on)***:***

Publications:

*
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Please complete the [secondments google sheet](https://docs.google.com/spreadsheets/d/1-eNy0gbfJLk2rj-iqzO2CyLso6uCpvEb/edit#gid=1369407323) and if the secondment didn’t take place please provide the justification in the column “L”.