RISEnergy

After the RISEnergy Transnational Access, Users are required to submit a User Report. This should be done within 4 weeks after the Access is completed unless otherwise agreed. The User Report will be given to the User(s) by the WP2 leader. The report contains sections related to the work performed, the main results and observations that were achieved.

This document should be completed, signed, and sent by e-mail to risenergy@for.kit.edu.

Summary questionnaire for Users who have been granted Transnational Access (TA) under the RISEnergy project Horizon Europe TA scheme. More information on RISEnergy TA can be found in "General Rules" and in "Access Policy" which can be found on the RISEnergy webpage.

Please complete, sign, and send this form, together with the Cost claim by e-mail to risenergy@for.kit.edu *with title: RISEnergy APPXXX - reports.*

General information about the project	
Project title (as used in Application)	First multi-beam TEM_{00}-mode Ce:Nd:YAG solar laser emission
Project number (APPXXX) and acronym (max 15 characters)	GA No. 101131793
RISEnergy RI(s) accessed	CNRS-PROMES-Medium and Small Solar Furnaces (MSSF)
Keywords (up to five, free text)	Solar, Lasers, TEMoo-mode, parabolic mirror, Ce:Nd:YAG
Arrival date (in town where RI is located)	14th of July, 2025 (First visit for Dawei Liang, Hugo Costa, and Sebastião Gomes). 24th of August, 2025 (Second visit for Dawei Liang, Hugo Costa, and Bruno Tibúrcio).
Departure date (from town where RI is located)	26th of July, 2025 (First visit for Dawei Liang, Hugo Costa and Sebastião Gomes). 6th of September, 2025 (Second visit for Dawei Liang, Hugo Costa, and Bruno Tibúrcio).
Starting date of Access (first day at RI)	15th of July, 2025 (First visit for Dawei Liang, Hugo Costa, and Sebastião Gomes). 25th of August, 2025 (Second visit for Dawei Liang, Hugo Costa, and Bruno Tibúrcio).
Finishing date of Access (last day at RI)	25th of July, 2025 (First visit for Dawei Liang, Hugo Costa and Sebastião Gomes). 5th of September, 2025 (Second visit for Dawei Liang, Hugo Costa and Bruno Tibúrcio).

Number of days not using the RI (during the above period)	2 (two Sundays, first and second visits)
Reason for not using RI those days (describe)	The not used days were two Sundays during the two visits
Number of days using the RI	10 days including one Saturday (First visit) 11 days including on Saturday (Second visit)
Number of Users granted Access (group size)	3 (First visit) 3 (Second visits)
Comments	
User	
User group leader or sole applicant (user group member 1)	
First name	
Last name	
Affiliation / Employer	
Country of Employer	
E-mail	
User travelling to RI?	
Comments	
User group member 2	
First name	
Last name	
Affiliation / Employer	
Country of Employer	
E-mail	
User travelling to RI?	
Comments	
User group member 3	
First name	
Last name	
Affiliation / Employer	
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User travelling to RI?	
Comments	
User group member 4	
First name	
Last name	

Affiliation / Employer	
Country of Employer	
E-mail	
User travelling to RI?	
Comments	
Please insert more fields if your groups had more than four members.	

Access Summary Report - work performed and initial results

Brief description of the objectives of your project (up to 200 words)

Firstly, a seven-beam Ce:Nd:YAG solar laser pumping prototype is to be built in the New University of Lisbon. The seven Ce:Nd:YAG rods, each with 1.9 mm diameter and 20 mm length, will be efficiently pumped within a single pump cavity through a fused silica secondary concentrator. When solar-pumped through the PROMES-CNRS MSSF parabolic mirror with 2.47 m^2 effective collection area, reaching 27.5 W/m^2 TEM_{00} mode solar laser collection efficiency.

Secondly, a four-beam Ce:Nd:YAG solar laser prototype was successfully built in New University of Lisbon in 2024. Four Ce:Nd:YAG rods, each with 2.0 mm diameter and 20 mm length, will be pumped within a single pump cavity through a fused silica secondary concentrator. When solar-pumped by the PROMES-CNRS MSSF parabolic mirror with 1.1 m^2 effective collection area, 19.1 W/m^2 TEM_{00} mode solar laser collection efficiency is expected.

Thirdly, a two-beam Ce:Nd:YAG solar laser was successfully built in New University of Lisbon in 2024. Two Ce:Nd:YAG rods, each with 3.0 mm diameter and 20 mm length, will be pumped within a single pump cavity through a fused silica secondary concentrator, capable of more than 19.4W TEM_{00} mode solar laser emission, when solar-pumped by the PROMES-CNRS MSSF parabolic mirror with 0.8 m^2 effective collection area.

Activities performed (up to 600 words)

[Please summarise the work carried you (steps taken, instrumentation used, techniques employed, data sources consulted etc.)]

1.The improvement of TEM_{00}-mode laser conditions is a key focus in solar laser research, especially for applications requiring low divergence and high-power density. Using multiple active media to mitigate thermal load is a promising strategy to enhance beam quality, scalability, and stability of laser output power.

However, to the best of our knowledge, no experimental research has been conducted on the emission of multiple TEM_{00}-mode solar laser beams.

Before our first visit to PROMES-CNRS, we designed and built a new four-beam laser head composed of an aspheric lens, a conical pump cavity, and four Ce:Nd:YAG rods in an end-side pump configuration, as shown in Fig.1.

In the first visit to the MSSF facility of PROMES CNRS, we successfully implemented and realized the first simultaneous emission of four high-quality TEM_{00}-mode solar laser beams, utilizing a heliostat-parabolic mirror system of the MSSF facility, as indicated by Fig. 1

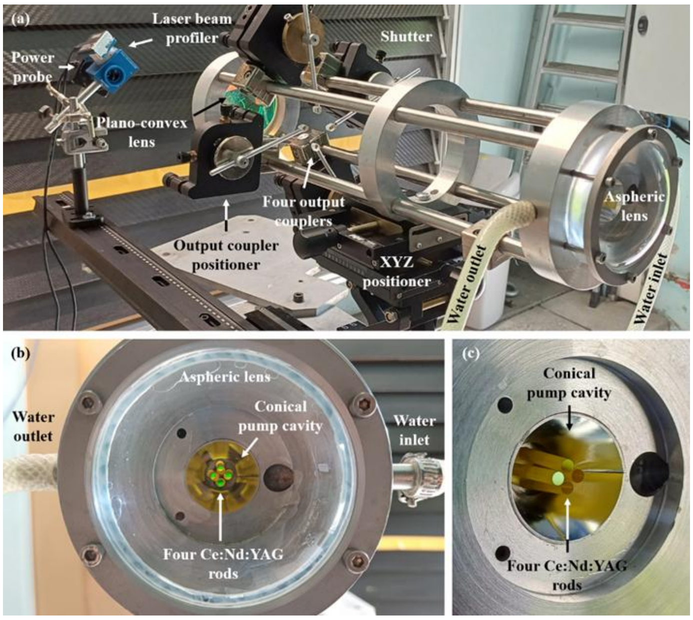

Fig. 1. Photograph of (a) the solar laser head positioned at the focal point of the parabolic mirror, (b) the frontal view of the laser head, and (c) the interior of the conical pump cavity.

2. Before our first visit to PROMES-CNRS, to largely reduce design the complexity and reduce the time consuming seven-beam laser cavity alignment process in PROMES-CNRS (might take more than two days to achieve all the accurate seven-beam laser cavities alignments), instead of building the proposed seven-TEM_{00} mode Ce:Nd:YAG solar laser prototype, we designed and built a new three-beam solar laser head with similar efficiency, composed of an aspheric lens, a conical pump cavity, and three Ce:Nd:YAG rods in an end-side pump configuration, as shown in Fig.2.

Consequently, in the first and second visits to PROMES-CNRS, we successfully realized the first simultaneous emission of three high-quality 1064 nm TEM_{00}-mode cw solar laser beams from a single laser head composed of a fused silica aspheric lens, a conical pump cavity, and three 2 mm diameter, 25 mm length Ce:Nd:YAG rods, which were actively cooled by water and solar-pumped through a heliostat-parabolic solar energy collection and concentration system of PROMES-CNRS.

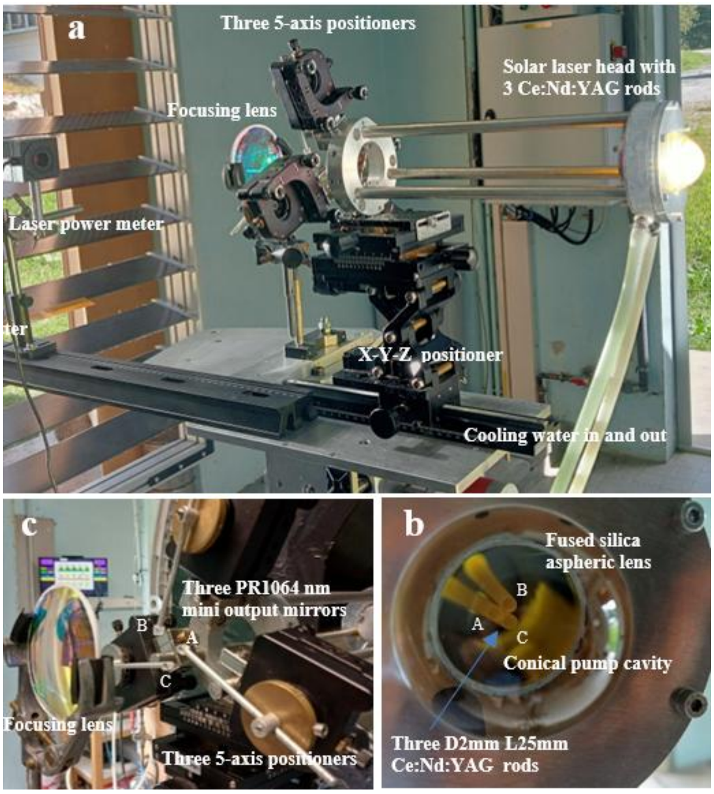

Fig. 2. Photograph of (a) the solar laser head positioned at the focal point of the parabolic mirror, (b) the interior of the conical pump cavity with three 2 mm diameter, 25 mm length Ce:Nd:YAG rods. (c) the back view of the laser head, showing the three mini PR1064nm output mirrors mounted on the three 5-axis positioners, respectively.

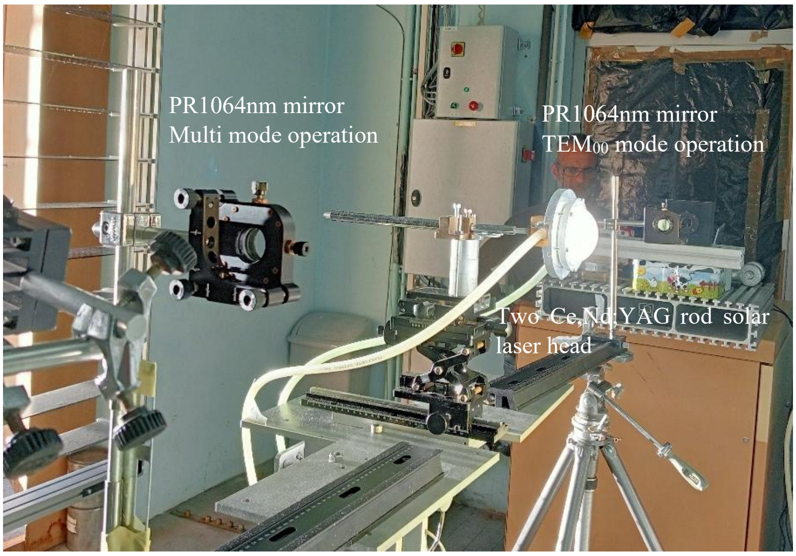

Fig. 3. Photograph of the first multimode and TEM_{00} mode-beam solar laser head positioned at the focal point of the parabolic mirror. The interior of the conical pump cavity of the solar laser head was mounted with two 3.2 mm diameter, 30 mm length Ce:Nd:YAG rods.

In the second visit to PROMES-CNRS, we also successfully realized the first simultaneous emission of multimode and TEM_{00}-mode cw solar laser beams from a single laser head composed of a fused silica aspheric lens, a conical pump cavity with the two 3.2 mm diameter, 30 mm length Ce:Nd:YAG rods, which were actively cooled by water and solar-pumped through a heliostat-parabolic solar energy collection and concentration system of PROMES-CNRS with 0.8 m^2effective collection area, as indicated by Fig.3.

Scientific results (up to 800 words)

[Summarise the (initial) outcomes of your study at the RI(s).]

1. In the first visit, with the four TEM_{00}-mode beam Ce:Nd:YAG solar laser head, a total TEM_{00}-mode laser power of 6.05 W was achieved, corresponding to an 8.77 W/m^2 collection efficiency and a 0.90% solar-to-laser power conversion efficiency; these efficiencies represent new benchmarks for Ce:Nd:YAG systems that incorporate parabolic mirrors, exceeding the previous records, set at the same MSSF solar facility, by factors of 1.87 and 1.43, respectively.

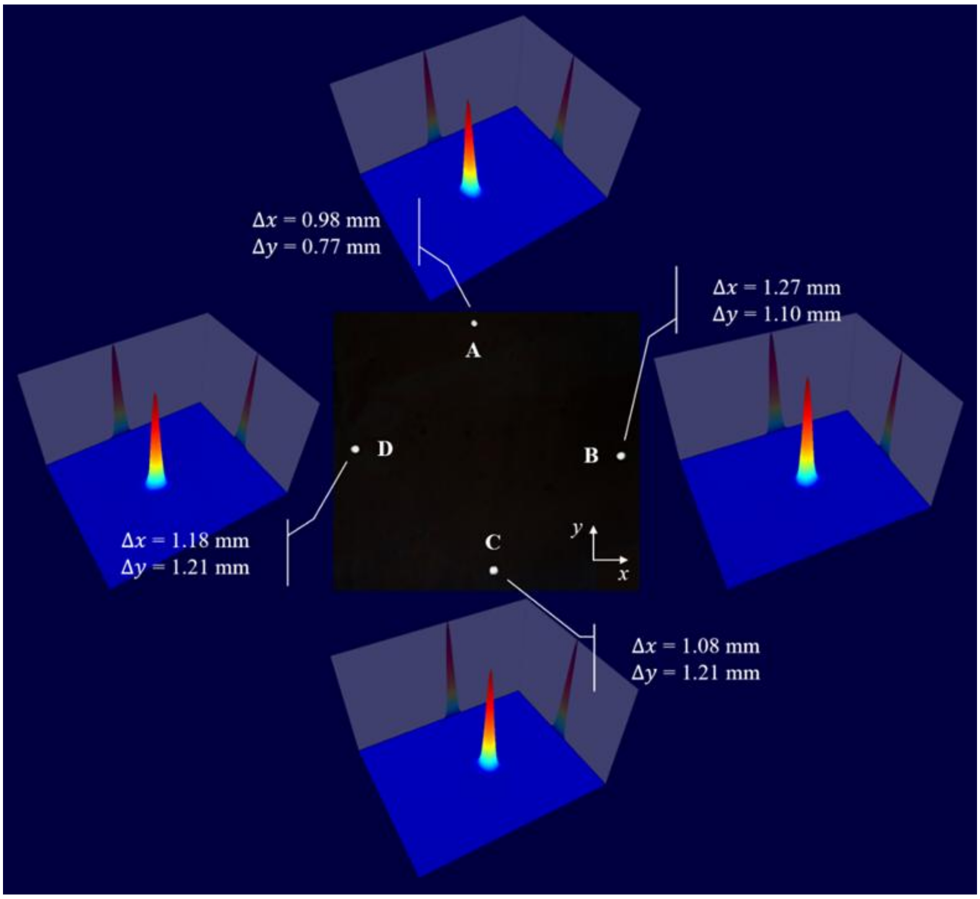

Fig. 4. 3D profiles of the laser beams A–D emitted from the four Ce:Nd:YAG rods, with a photograph of the perforations at the center, done 120 mm away from the output couplers. The laser beam diameters measured at this position are also presented.

The Gaussian profiles of the TEM_{00}-mode laser beams (A–D) produced by the four Ce:Nd:YAG rods are shown in Fig. 4, as recorded with the CinCam CMOS UV-NIR beam profiler from CINOGY. It also shows the perforations produced by these laser beams simultaneously, measured 120 mm away from the output couplers. Based on the perforations executed at this position, the laser beam diameters were measured along the x- and y-axes: beam A was characterized by Δx = 0.98 mm, Δy = 0.77 mm; beam B by Δx = 1.27 mm, Δy = 1.10 mm; beam C by Δx = 1.08 mm, Δy = 1.21 mm; and beam D by Δx = 1.18 mm, Δy = 1.21 mm.

2. In the first and second visits, we successfully realized the first simultaneous emission of three 1064 nm TEM_{00}-mode cw solar laser beams from a single laser head composed of a fused silica aspheric lens, a conical pump cavity, and three 2 mm diameter, 25 mm length Ce:Nd:YAG rods, which were actively cooled by water and solar-pumped through a heliostat-parabolic solar energy collection and concentration system of the PROMES-CNRS.

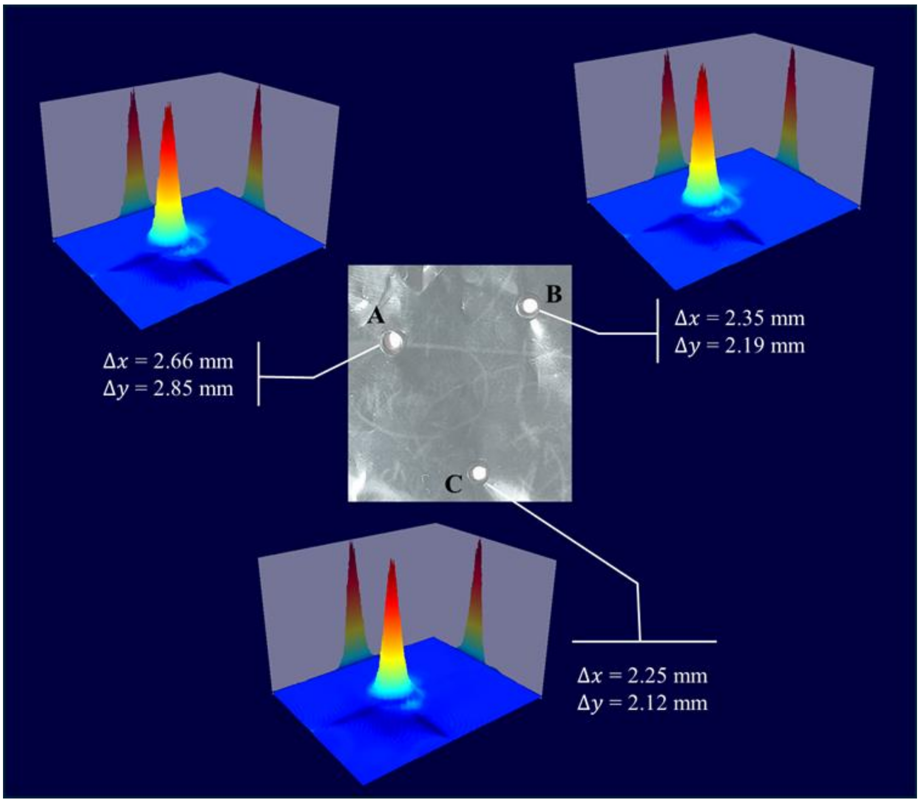

Fig. 5. 3D profiles of the high quality TEM_{00}-mode laser beams A, B and C emitted from the three Ce:Nd:YAG rods, as well as a photograph showing the perforations effects on plastic, positioned 120 mm away from the output couplers. The laser beam diameters (Δx and Δy) measured at this position are also given, indicating a high quality of these three TEM_{00}-mode Gaussian-shaped laser beams.

When the heliostat mirror was aligned to the three input faces of the three 2 mm diameter, 25 mm length Ce:Nd:YAG rods within the conical pump cavity through the fused silica aspheric lens, a maximum total laser power of 2.61 W in TEM_{00}-mode regime was finally measured with an incoming solar power of 365.7 W, yielding a collection efficiency of 6.71 W/m^2 and a solar-to-laser power conversion efficiency of 0.71%. As shown in Fig. 5, the Gaussian profiles of the TEM_{00}-mode laser beams (A, B and C) produced by the three Ce:Nd:YAG rods are shown in Fig. 4, as recorded with the CinCam CMOS UV-NIR beam profiler from CINOGY. It also shows the simultaneous perforations on plastic produced by these laser beams, measured 120 mm away from the output couplers. Based on the perforations executed at this position, the laser beam diameters were measured along the x- and y-axes: beam A was characterized by $\Delta x = 2.66$ mm, $\Delta y = 2.85$ mm; beam B by $\Delta x = 2.35$ mm, $\Delta y = 2.19$ mm; and beam C by $\Delta x = 2.25$ mm, $\Delta y = 2.12$ mm, all indicating high quality fundamental mode laser beam profiles with rotational symmetries.

3. To the best of our knowledge, there is no report on the successful simultaneous solar laser emissions of both multimode and fundamental mode regimes, in side-pumping approach. Therefore, we herein successfully designed, built and tested the first two-rod side-pumping Ce:Nd:YAG multi-regime solar-pumped laser, simultaneously emitting TEM_{00}-mode and multimode solar laser beams with enhanced stability. The multimode and TEM_{00}-mode solar laser beam profiles were measured by CINOGY profiler, as shown by Fig. 6.

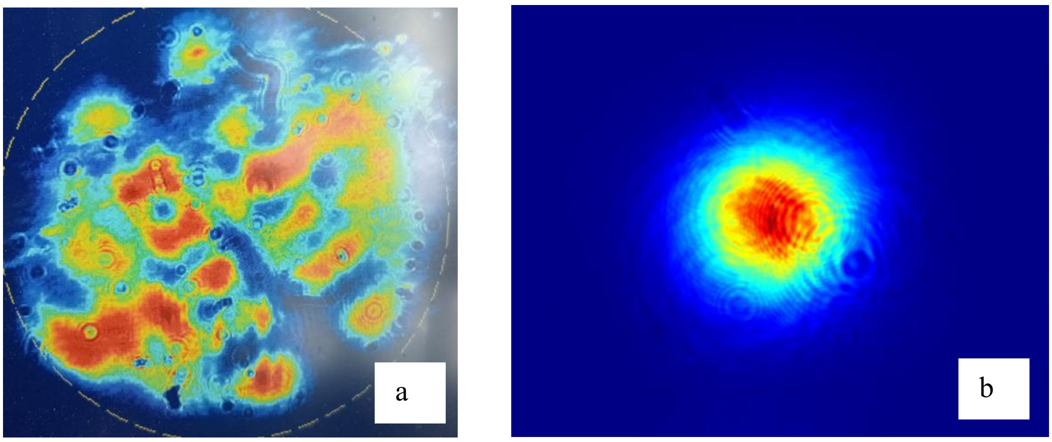

Fig. 6 (a) Multimode and (b) high-quality TEM_{00}-mode solar laser beam profiles from the two Ce:Nd:YAG rod solar laser.

Interpretation of the results (up to 400 words)

[Discuss the data obtained and describe the major scientific conclusions drawn.]

1. An assessment of a solar laser prototype, composed of an aspheric lens, a conical pump cavity, and four Ce:Nd:YAG rods, was conducted at the MSSF of PROMES-CNRS, with a parabolic mirror as the primary

concentrator. The objective was to produce multiple TEM_{00}-mode solar-pumped laser beams concurrently, which, to our knowledge, had not been achieved before. With an effective collection area of 0.792 m^2, a total TEM_{00}-mode laser power of 6.05 W was attained, corresponding to a collection efficiency of 7.64 W/m^2 and a solar-to-laser power conversion efficiency of 0.79%. In comparison to the outcomes of a single-rod prototype tested at the same MSSF facility, which had reached the highest efficiencies in TEM_{00}-mode regime for Ce:Nd:YAG systems that employed the parabolic mirror, the four-rod prototype's collection and conversion efficiencies were 1.63 and 1.25 times higher, respectively.

2. The three-beam Ce:Nd:YAG solar laser prototype which incorporated the fused aspheric lens, the conical pump cavity, and the three 2 mm diameter, 25 mm length Ce:Nd:YAG rods with cooling water, was designed and developed in Lisbon and tested at the MSSF laboratory of the PROMES-CNRS. Three TEM_{00}-mode cw solar laser beams were successfully produced, which, to the best of our knowledge, had not been attained before. With the effective collection area of 0.389 m^2, the total TEM_{00}-mode laser power of 2.61 W was measured, corresponding to a collection efficiency of 6.7 W/m^2 and a solar-to-laser power conversion efficiency of 0.71%. In comparison to the outcomes of the single Ce:Nd:YAG rod prototype tested at the same MSSF facility, the three-rod prototype's collection and solar-to-laser conversion efficiencies are 1.43 and 1.13 times higher, respectively. More importantly, the introduction of three thin Ce:Nd:YAG rods have considerably improved the total fundamental mode laser output power stability and heliostat orientation error compensation capacity, as compared to the previous 2 mm diameter 35 mm length single-Ce:Nd:YAG prototype pumped by a Fresnel lens.

3. The first two-rod side-pumping Ce:Nd:YAG multi-regime solar powered laser was built in Lisbon and tested in PROMES, emitting TEM_{00}-mode and multimode solar laser beams. The solar laser head, where two 3.2 mm diameter and 30 mm length Ce:Nd:YAG laser rods were mounted, was solar-pumped by the heliostat-parabolic system of the MSSF of the PROMES-CNRS. A total solar laser power of 7.3 W was measured in the first simultaneous multi-regime solar laser emission, being 5.2 W solar laser output power in multimode emission and 2.1 in TEM_{00}-mode emission, leading for the multi-regime operation to 1.47% solar-to-laser conversion efficiency and 13 W/m^2 collection efficiency for the multimode emission, and 0.61% solar-to-laser conversion efficiency and 5.2 W/m^2 collection efficiency for the TEM_{00}-mode emission.

Problems encountered: While parabolic mirrors can effectively concentrate sunlight into a small area without chromatic aberration, the blockage of sunlight by the laser head and its supporting structure in front of the parabolic mirror has constrained considerably the practicality of this primary concentrator. This shadowing effect is particularly disadvantageous for the uniform and simultaneous emission of three TEM_{00}-mode laser beams, since it is usually difficult to achieve uniform and symmetrical solar pump light distribution on the three Ce:Nd:YAG rods.

Employing a Fresnel lens may ensure that sunlight remains unobstructed, allowing the laser head to be placed at the centre of the focal spot, where solar pump light distribution is much more symmetrical, as compared to that by the parabolic mirror scheme, and consequently facilitating the simultaneous production of multiple TEM_{00}-mode laser beams, each emitting a high brightness fundamental mode beam with the similar output power level, capable of ensuring many interesting and demanding terrestrial and space applications.

More importantly, to achieve the uniform pumping of multi-Ce:N:YAG rods within a single pump cavity, in 2026 RISenergy call, we plan to propose a novel Cassegrain-type solar energy concentration system, based on the present MSSF solar facility, where a cooled aspheric dichroic mirror will be mounted before the focal spot of the 2 m diameter parabolic mirror of the MSSF, reflecting the incoming solar power to behind the parabolic mirror, through its 30 cm diameter central hole, for the uniform pumping of a novel four-beam Ce:Nd:YAG solar laser. In this way, the shadowing effect of the classical parabolic mirror can be avoided, permitting the uniform pumping of the four Ce:Nd:YAG rods simultaneously. More importantly, the addition of the dichroic mirror can let pass the unnecessary infrared (IR) heat from the Sun and reflect only the useful solar power within the 350 nm-900 nm band, which is considered a very important step to achieve new solar laser efficiency record and laser beam stability, due to the absence of the IR heat as compared to today´s solar laser systems.

Main achievements during the TA related work (up to 250 words)

[Describe the main achievements during your stay at the site(s), Outputs (results, publications, models, etc.), conclusions, next steps, potential impact]

Three multi-beam TEM_{00}-mode cw Ce:Nd:YAG solar laser prototypes were built and Lisbon and all successfully tested in the MSSF facility, emitting high-quality Gaussian-shaped fundamental mode laser beams.

A: For the four-beam solar laser, we achieved the following highlights:

1. First simultaneous emission of three TEM_{00}-mode solar laser beams.
2. 8.77 W/m^2 record solar laser collection efficiency by a parabolic mirror.

3. 0.90% record TEM_{00}-mode solar-to-laser conversion efficiency by a parabolic mirror.

These efficiencies represent new benchmarks for Ce:Nd:YAG systems that incorporate parabolic mirrors, exceeding the previous records, set at the same facility, by factors of 1.87 and 1.43, respectively.

4. Focusing four TEM_{00}-mode solar laser beams for demanding material processing applications.

B. For the three-beam fundamental mode solar laser, we achieved the following highlights:

1. First simultaneous emission of three TEM_{00}-mode solar laser beams.
2. 6.70 W/m^2 record solar laser collection efficiency by a parabolic mirror.
3. 0.71% record TEM_{00}-mode solar-to-laser conversion efficiency by a parabolic mirror.

These efficiencies represent new benchmarks for Ce:Nd:YAG systems that incorporate parabolic mirrors, exceeding the previous records, set at the same facility, by factors of 1.43 and 1.13, respectively.

4. Focusing three TEM_{00}-mode solar laser beams for many demanding material processing applications, as shown in the following figures. As shown in Fig.7.

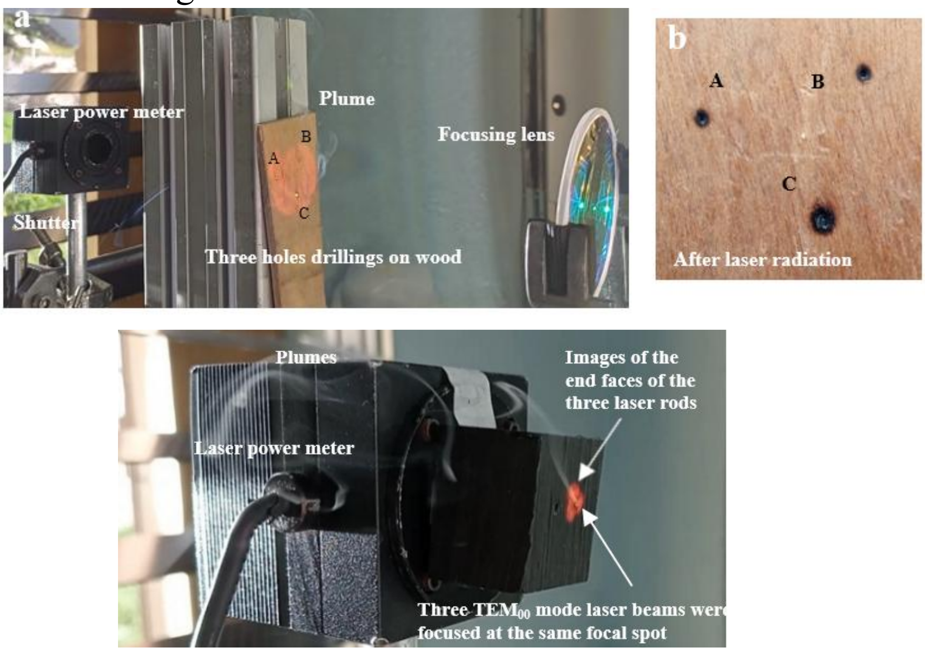

Fig.7 Three-beam TEMoo-mandode Ce:Nd:YAG solar laser wood burning. (a) Three TEMoo-mode laser beams in action. (b) Burning effects after the three-beam solar laser radiation. (c) Focusing three Ce:Nd:YAG cw solar laser beams to a single focal spot. Considerable number of plumes were generated from the focal spot of the three TEM_{00}-mode 1064nm invisible laser beams. A symmetrical orange color image of the three Ce:Nd:YAG rods output end faces was also formed around the central focused 1064 nm beam spot.

C: For the two-beam solar laser, we achieved the following highlights:

We built and tested the first two-rod side-pumping Ce:Nd:YAG multi-regime solar powered laser, simultaneously emitting two TEM_{00}-mode and multimode solar laser beams with enhanced stability. The solar laser head with two 3.2 mm diameter and 30 mm length laser rods was solar-pumped by the heliostat-parabolic system of PROMES-CNRS.

A total solar laser power of 7.3 W was measured in the first simultaneous multi-regime solar laser emission, being 5.2 W solar laser output power in multimode emission and 2.1 in TEM_{00}-mode emission, leading for the multi-regime operation to 1.47% solar-to-laser conversion efficiency and 13.0 W/m^2 collection efficiency for the multimode emission, and 0.61% solar-to-laser conversion efficiency and 5.2 W/m^2 collection efficiency for the TEM_{00}-mode emission. High quality fire was successfully melted under 5.2W multimode solar laser power via a focusing lens, revealing its great usefulness for laser material processing, as shown in Fig. 8.

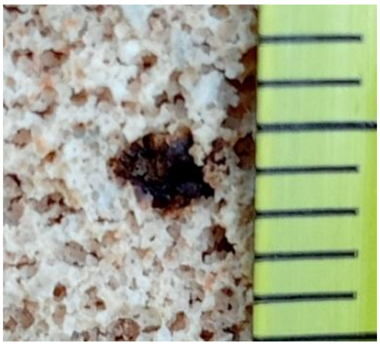

Fig.8 High quality fire brick was successfully meted by the 5.2W cw multimode solar power in several second. An additional focusing lens (f= 25mm) was used to achieve a quick melting effect, revealing bright future for the solar laser applications in material processing.

Data Management

[Describe the further usage and storage of project data. State where the data will be kept and name a person responsible for the data. Define data]

Research data management is the cornerstone of a successful research project, and yet it often remains an underappreciated art that gets overlooked in the hustle and bustle of everyday research even when required by funding bodies. We then need to manage the data associated with their research projects effectively, according to the rules of data management of RISenergy EU project proposal. It is imperative to plan our date management strategies early on, as indicated by the RISenergy EU project proposal and setup our project organisation before embarking on the research.

There are several different factors to consider: data management plans, data organisation and storage, publishing and sharing your data. We submitted two manuscripts to Applied Optics (four TEM_{00}-mode beam solar laser emission, in review) and Optik (three TEM_{00}-mode beam solar laser emission, with Editor), and will submit another manuscript on two Ce:Nd:YAG solar laser emission to Solar Energy Materials and Solar cells, consequently, storing and sharing our data tasks are ensured, as well the divulgation of our research results.

Additionally, it is important to reflect upon the ethical implications that might need to be planned for, and adverse issues that may need a mitigation strategy. Since we are working on renewable solar-powered lasers, there are no ethical issues involved. We have successfully built and tested the simultaneous emission of TEM_{00}-mode solar laser beams, very useful for many solar laser applications without involving any electrical equipment, so the mitigation strategy of ensuring multi-beam solar laser emission is more than ensured.

Difficulties during the TA related work (up to 250 words)

[List problems and issues, you had, completing out your research project: Did you get access to all the necessary equipment, facilities, databases, etc.?
If not, please specify the problems that occurred and list equipment the was not working or accessible.]

Despite our considerable successes in the first and simultaneous emission of four, three and two TEM_{00}-mode cw solar laser beams from the MSSF facility of the PROMES-CNRS, using the three solar laser prototypes we built in Lisbon, we still met with the following difficulties in term of future improvement for the MSSF solar energy collection and concentration system:

1. The planes mirrors mounted on the solar heliostat were not correctly aligned to the 2-meter diameter parabolic mirror, their alignment error might have reached reach a few degrees, which negatively influenced our laser output results, as compared to the numerical simulation results in our proposal.

2. The 2-meter diameter MSSF parabolic mirror presented more small damages on its surface, as compared to our previous research visit with the framework of SFERA programs.

3. The cooling water for the horizontal axis SMMF facility was provided from the mountain spring water, without any temperature control, and the water pressure was also low, this shortcoming can be resolved by buying a profession chiller with 6-10 Litter/min flow rate.

Intended publications

[Explain where and how you expect to publish the outcomes of your project work. Include also anything already published (What and where?)]

1. Manuscript submitted to OPTIK (with Editor), (Elsevier, IF3.8)

Simultaneous emission of three TEM_{00}-mode Ce:Nd:YAG solar laser beams from a single pump cavity

Dawei Liang[1,*], Hugo Costa[1], Bruno D. Tibúrcio[1], Cláudia R. Vistas[1], Anita Haeussler[2], Emmanuel Guillot[2], and Joana Almeida[1]

[1]*Centre of Physics and Technological Research, Department of Physics, NOVA School of Science and Technology, 2829-516 Caparica, Portugal*
[2]*PROcédés Matériaux et Energie Solaire – Centre National de la Recherche Scientifique, 66120 Font-Romeu-Odeillo-Via, France*

2. Manuscript submitted to Applied Optics (In review) (OSA, IF1.7)

Simultaneous emission of four TEM_{00}-mode solar-pumped laser beams

Hugo Costa,[1] Dawei Liang,[1,*] Sebastião Gomes,[1] Joana Almeida,[1] Bruno D. Tibúrcio,[1] Anita Haeussler,[2] Emmanuel Guillot,[2] and Cláudia R. Vistas[1]

[1]*Centre of Physics and Technological Research, Department of Physics, NOVA School of Science and Technology, 2829-516 Caparica, Portugal*
[2]*PROcédés Matériaux et Energie Solaire – Centre National de la Recherche Scientifique, 66120 Font-Romeu-Odeillo-Via, France*

3. **Manuscript** (to be submitted) to Solar Energy Materials and Solar Cells (Elsevier, IF 6.3)

Stable dual-rod side-pumping Ce:Nd:YAG Solar powered laser in simultaneous multimode/TEM_{00}-mode multi-regime operation

Bruno D. Tibúrcio[1], Dawei Liang[1,], Hugo Costa[1], Joana Almeida[1], Anita Haeussler[2], Emmanuel Guillot[2] and Cláudia R. Vistas[1]*
[1]*Centre of Physics and Technological Research, Department of Physics, NOVA School of Science and Technology, 2829-516 Caparica, Portugal*
[2]*PROcédés Matériaux et Energie Solaire – Centre National de la Recherche Scientifique, 66120 Font-Romeu-Odeillo-Via, France*

Expected impact

[The impact the expected results will have on current and future research or practice, public safety, European standardization, competitiveness, integration and cohesion and on sustainable growth. any follow-on proposals, projects, collaborations, commercialisation]

Despite the huge efforts to improve the efficiency of multimode solar lasers worldwide, the inferior quality of their laser output beam constitutes a significant technical limitation to accomplishing many demanding solar laser applications. The exploitation of small-diameter laser rods can lead to significant improvement in laser output beam quality M^2 factors and their thermal resistance. Notable improvement in output laser beam quality was attained by adopting four, three and two small diameter Ce:Nd:YAG rod for the efficient extraction of TEM_{00}-mode solar laser beams, during our two research visits to the MSSF solar facility in the PROMES-CNRS in 2025.

TEM_{00}-mode operation is a must for many demanding laser-based applications due to the small divergence and high-power density of the emitted laser beam. To the best of our knowledge, there is no report on the emission of multiple TEM_{00}-mode solar laser beams up until now.

In this regard, our solar laser prototypes, emitting simultaneously four, three and two TEM_{00}-mode cw solar laser beams, solar-pumped through the MSSF infrastructure of the PROMES-CNRS, with, most hopefully, provide strong influence on laser applications. For example: solar-pumped multi-beam TEM_{00}-mode solar laser systems could significantly influence the broader pattern of laser energy generation, offering the supply of plentiful renewable laser energy, particularly in off-grid zones with high solar irradiance. Consequently, this TEM_{oo}-multibeam solar laser technology will draw attention not only for terrestrial applications, such as materials processing and hydrogen extraction from ammonia-water, optical communications, and the wireless charging of electric vehicles, but also, and more importantly, for space applications, particularly in long distance power transmission, laser propulsion, and free-space optical communication.

Conclusions / additional comments

[Provide any other comments you might have on your work]

No.

Did you complete the European Commission User questionnaire https://ec.europa.eu/eusurvey/runner/RIsurveyUSERS?

☐ *Yes* ☐x *No*

Feedback – HSE, Ethics and Satisfaction

Please rate on a scale from 1 (excellent) to 5 (poor). Feel free to provide additional comments

	1 (excellent)	2	3 (neutral)	4	5 (poor)
Practical information on how to apply for Transnational Access and the overall application process	X☐	☐	☐	☐	☐

Comment	
Information provided, once your project was accepted, on how to proceed	1 (excellent): X☐ · 2: ☐ · 3 (neutral): ☐ · 4: ☐ · 5 (poor): ☐
Comment	
Support received at the site(s) regarding technical/scientific matters and logistics	Have you got sufficient support from the RI staff during the project? If not, please, specify the problems. X☐ *Yes* ☐ *No*
Please specify any problems	
RI extension / upgrades required	In your opinion, is the RI needed to be upgraded? If yes, please give an explanation. X *Yes* ☐ *No* The MSSF solar facility was good for normal high temperature material processing applications, however, for high-flux solar laser applications, we wish we could have the heliostat mirror better aligned, the parabolic mirror replaced by a new one and the cooling water system upgraded.
Please specify	
Problems with local regulations	Have you had any problems with regulations of the visited RI owner (HSE, lab working hours, etc.)? If yes, please, specify ☐ *Yes* *x*☐ *No*
Please specify	
Health and safety issues	Did you encounter any health or safety issue during your research? Please provide details. ☐ *Yes* *x* ☐ *No*
Please provide details	
Environment & Ethics	Did your research involve the use of elements that may cause harm to the environment, to animals or plants? Please provide details. ☐ *Yes* *x* ☐ *No*
Please provide details	
Environment & Ethics	Did your research deal with endangered fauna and/or flora and/or protected areas? Please provide details. ☐ *Yes* *x*☐ *No*

Please provide details	
Environment & Ethics	Did your research involve the use of elements that may cause harm to humans, including research staff? Please provide details. ☐ *Yes* x☐ *No*
Please provide details	
Environment & Ethics – Dual use	Does your research have the potential for military applications? Please provide details. x☐ *Yes* ☐ *No* *High quality multi-beam TEM_{00}-mode solar laser will be a useful tool for defence applications such as the interception of incoming drones.*
Please provide details	
Environment & Ethics – Misuse	Does your research have the potential for malevolent /criminal/terrorist abuse? Please provide details. ☐ *Yes* *x No*
Please provide details	
Environmental issues	Were any potentially dangerous substances (materials / gases etc.) released into the environment (atmosphere, water, or land)? Please provide details. ☐ *Yes* *x* ☐ *No*
Please provide details	
Ethics issues	Are there any other ethics issues that should be taken into consideration? Please specify ☐ *Yes* x *No*
Please provide details	

Overall impression of communication and interaction after finishing your TA and related work	1 (excellent)	2	3 (neutral)	4	5 (poor)
	x ☐	☐	☐	☐	☐

Comment	
Suggestions for facilities not included in RISEnergy which you would use for your research	
[Please provide suggestions for specific type of facilities missing (RI gaps) or measurement / experiments you would like to perform which cannot be done on current RISEnergy facilities.] **No**.	

Suggestions how RISEnergy can improve future TA programme, how to make the TA more impactful and how to enable the achievement of high TRL levels
[Your suggestions] Upgrading the MSSF solar facility will help greatly the TEM_{00}-mode solar laser efficiencies.

Feedback – Pro-active Innovation Support

Awareness	Did you know about the pro-active innovation support of RISEnergy? ☐ Yes ☒ No
[Please specify how you learned about the pro-active innovation support]	
Personal experience	Have you taken advantage of or benefited from the pro-active innovation support? ☐ Yes ☒ No
[*Please provide details*]	
Information/service provided by the pro-active innovation support?	1 (excellent) ☐ / 2 ☐ / 3 (neutral) ☒ / 4 ☐ / 5 (poor) ☐
[*Please provide details*]	

I declare that the above provided information and especially that information on the number of days visited the RI is correct.

☒ *I have read the RISEnergy privacy policy for participation in the RISEnergy TA and consent to participation and the associated data processing.*

Your full name: I

Your signature:

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