Answers to Reviewers

We thank the Reviewers for their effort and comments in providing feedback for the manuscript. We have addressed all the concerns below and provided our response in a point-by-point manner. We have colored our responses and separated them by markers for Reviewer's convenience. Thanks to the valuable criticism, we improved the quality of the manuscript and hope it can be published.

We made many small and large revisions relating to the Reviewers comments to the Main text. Because we cannot upload the new version of Manuscript the submission system, we attached the marked up and revised Manuscript to the end of this file for the Reviewer's convenience. We have marked up the significant changes associated with significant improvements, but small changes to spelling and grammar are not marked up.

In addition, we have received a suggestion from the Editorial staff to transfer our manuscript to the Special issue titled "Optical Properties of Semiconductor Nanomaterials: 2nd Edition", which we agreed to.

On behalf of all Authors,
dr. Darius Gailevicius

Reviewer Nr 2

- Comment by the Reviewer:

Review of the paper „Spatially structured optical pump for laser generation tuning"

Paper describes the emission properties of MECSEL laser. Reports an excellent experiments which are well performed and explained. The conclusion are well formulated.

- Response:

We thank the Reviewer for the positive feedback and constructive criticism offered below. We tried to address each point of criticism below and think managed to improve the quality of the manuscript significantly.

- Comment by the Reviewer:

Weak points:

Described research has nothing to do with nanomaterials, especially with 2D or Carbon Nanomaterials. It is out of scope of the journal.

- Response:

Although the direct connection to nanomaterials, particularly 2D or Carbon Nanomaterials, is not explicitly outlined in the manuscript, the principles and technologies developed in this research will lead to potential applications in the field of nanomaterials. For instance, precise control over laser beam shape and quality is crucial in processes like laser-induced fabrication, modification, or characterization of nanomaterials. In addition, it should be considered that the structured pump is also relevant for photonic crystal laser structures, where the cavity design is planar.

However, it is the future and might not be relevant for the current special issue. We agree with the Reviewer that this is good observation and have been contacted by the Editors for transferal to another Special Issue "Optical Properties of Semiconductor Nanomaterials: 2nd Edition.

- Comment by the Reviewer:

Paper is written with poor English. Has to be corrected.

The text should be prepared with greater care. Naw the text is often difficult to understand. The colloquial language is used. English native speaker has to read the paper and correct the grammar or use commercially provided help by https://www.proof-reading-service.com/en/ , for instance.

- Response:

We thank the Reviewer for this observation; upon revisiting the text, we have revised with great attention to detail.

- Comment by the Reviewer:

In introduction I would suggest to provide information that your research is on "optical pumping", "disc laser", "diode pumping " Take care to call particular laser always the same

- Response:

It is a valuable observation. We introduced clarification in the introduction section (see ending) and now it reads: "In this work, we investigate whether a novel mode of operation can be achieved via structured optical pumping. A diode-pumping approach and a surface-emitting membrane semiconductor active medium characterize our particular approach."

- Comment by the Reviewer:

VECSEL are not vertical surface emitting lasers

- Response:

Thank you for the observation. We made correction to properly referred to them as Vertical External Cavity Surface Emitting Lasers

- Comment by the Reviewer:

MECSEL are not membrane external cavity laser

- Response:

Thank you for the correction. We made amendments the text to read Membrane External Cavity Surface Emitting Lasers.

- Comment by the Reviewer:

What is "Surface-emitting lasers" L45

- Response:

Additional explanation added to the beginning of the paragraph: "The compact surface emitting microchip lasers are gaining more and more interest for their potential applications in data transfer and metrology [19]. Their ability to emit light from the surface as opposed to those emitted from the edge in more common semiconductor lasers allows them to be clustered into large 2D arrays"

- Comment by the Reviewer:

Cavity or resonator ?

- Response:

We have revised the text to consistently refer to it more often as (Optical) Cavity.

As far we can tell, the terms are synonymous, and we could not find any preference for one over another is different glossaries. For example:

William T. Silfvast, in Encyclopedia of Physical Science and Technology (Third Edition), 2003

III.D Optical Cavity (Optical Resonator)

The optical cavity or resonator is typically comprised of a mirror at each end of the elongated gain region (see Fig. 1). <…>

- Comment by the Reviewer:

Same errors and suggestions noticed by reviewer (not all present in the paper).

L13 "For high-power approaches large pump areas" may by " For high-power application large pump areas…" would be better.

- Response:

We thank the Reviewer for pointing this out and we made amendments accordingly.

- Comment by the Reviewer:

L16 "In order to further improve both laser parameters some aspects of the laser have to be modified." Please remove sentence since it do not provide any information.

- Response:

The sentence has been removed.

- Comment by the Reviewer:

L17/21 "Also, a Gaussian shape isn't the best option for all applications and other shapes are desirable. For a more uniform laser microfabrication, a flat-top beam gives better results and more control [2,3]. For high aspect ratio structures a Bessel beam is required [4]. However,

most of the time resonators are designed to output a fundamental Gaussian mode."

Try to provide this information in new order "Most often the resonators are designed to output a fundamental Gaussian mode. However, a Gaussian shape isn't the best option for all applications and other shapes are desirable. For a more uniform laser microfabrication, a flat-top beam gives better results and more control [2,3]. For high aspect ratio structures a Bessel beam is required [4]." For reader it is easier to understand if it first get general information then the exceptions.

If you write the information in other way the reader get filling that you deny yourself, that those exceptions are not important. This also suggest that your research is not important because you show results for a certain particular resonator.

- Response:

We thank the Reviewer for offering such a detailed perspective and agree that phrasing has paradoxically undermined our own concept.

We have amended the text to following the suggestions above and now it reads:

“Most often the resonators are designed to output a fundamental Gaussian mode. However, a Gaussian shape is not the best option for all applications, and other shapes are desirable. For a more uniform laser microfabrication, a flat-top beam gives better results and more control [2, 3]. For high-aspect ratio structures, a Bessel beam is required [4].”

- Comment by the Reviewer:

L24 are you sure the words “(extracavity modulation)” should be in this line ?

- Response:

We see that our formulation is confusing to the reader. We meant to communicate an emphasis on the modulation occurs on the pump beam outside the cavity, but the effects are felt by the cavity. Whereas intracavity modulation means that modifications are directly done inside the resonator (by adding filters or using SLM as one of the mirrors).

We have amended the relevant section to read: “Technically, this approach facilitates interaction with the gain media without mechanical or electrical manipulation of the resonator. Examples that would be in contrast, include loss inducing metalic meshes and other ways of manipulating the cavity [A,B,C].”

[A] I. Sagnes, M. Myara, A. Garnache, M. Sellahi, M.S. Seghilani, G. Beaudoin, X. Lafosse, L. Legratiet, P. Lalanne, Generation of new spatial and temporal coherent states using VECSEL technology: VORTEX, high order Laguerre-Gauss mode, continuum source, 10563 (2017) 23. https://doi.org/10.1117/12.2304083.

[B] M. Seghilani, M. Myara, I. Sagnes, B. Chomet, R. Bendoula, A. Garnache, Self-mixing in low-noise semiconductor vortex laser: detection of a rotational Doppler shift in backscattered light, Opt. Lett. 40 (2015) 5778. https://doi.org/10.1364/ol.40.005778.

[C] M.S. Seghilani, M. Myara, M. Sellahi, L. Legratiet, I. Sagnes, G. Beaudoin, P. Lalanne, A. Garnache, Vortex Laser based on III-V semiconductor metasurface: Direct generation of coherent Laguerre-Gauss modes carrying controlled orbital angular momentum, Sci. Rep. 6 (2016) 1–12. https://doi.org/10.1038/srep38156.

- Comment by the Reviewer:

L38 " The newer microchip lasers.." newer in regards to what ?

- Response:

We tried to clarify that we contrast them with edge emitting lasers. We rephrased sentence: The compact surface emitting microchip lasers are gaining more and more interest for their potential applications in data transfer and metrology [19]. Their ability to emit light from the surface as opposed to those emitted from the edge in more common semiconductor lasers allows them to be clustered into large 2D arrays.

- Comment by the Reviewer:

L48 " have higher beam quality and higher output power" in comparison to what ?

- Response:

We have amended this section to continue and read: "when compared to monolithic designs."

- Comment by the Reviewer:

L47-L48 SSL disc laser are made from different materials than the semiconductor based MECSELs thus the information provided here should be more precise

- Response:

We think that our text was confusing. The confusion might arise because we mentioned "microchip", which is a term used for solid-state diode pumped rare-earth metal doped lasers. We clarified that we are referring in this place to semiconductor systems and now the part reads: "monolithic semiconductor chip (containing the backmirror and active media)".

- Comment by the Reviewer:

L50 what is BA device

- Response:

We see that this section was not clear. We have amended this text to read: “To further optimize the beam parameters of micro-lasers a two-dimensional (2D) periodic modulation in gain and refractive index can improve beam quality”

We are referring to a broad area (BA) edge emitting laser or amplifier. Where the emitting region is of a rectangular shape with high asymmetry (has a slow and fast axis).

- Comment by the Reviewer:

L55 compare the ref. [28] with https://theses.hal.science/tel-02049651/file/50665_SEGHILANI_2015_archivage_cor.pdf and with papers of Montpellier team.

- Response:

The wire used in ref [28] is of 150 um diameters, whereas the structures for LG generation mentioned in chapter 6 were with subwavelength size. A metal mask approach was shown for VECSEL mode tuning. This is the “intra-cavity” approach, compared to the “extra-cavity” idea of tuning the optical pump. This comparison fits well in that location in text. For brevity we have included these examples by reference.

Please see the previous comment and response on L24 “(extracavity modulation)”.

- Comment by the Reviewer:

I would advise to concentrate the paper on the semiconductor based optically pumped MECSELs and VECSELs . Please get rid of the references to gas lasers and SSL, this will make introduction to your paper more clear. In conclusion at the end of the paper you can write that your reserch is universal for all disc laser.

- Response:

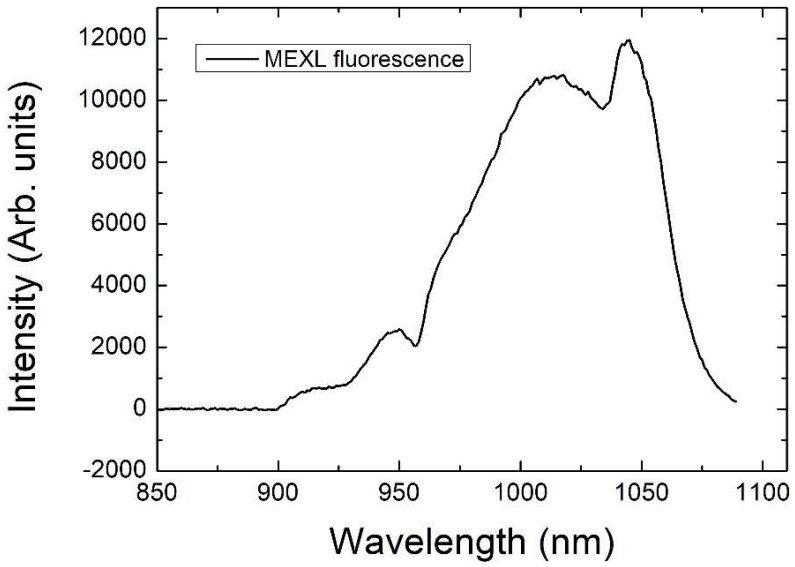
We revised the text to avoid distracting the reader by referring to systems that would be off topic. We avoid using the term “microchip” that we think confused the reader to think about solid-state systems such glass or dielectric crystal matrix lasers.

- Comment by the Reviewer:

L133 "To see the effects of the structured pump on the active layer itself, the luminescence of the beam shape was visualized onto a CCD beam profiler" The sentence is not precise enough. you have not see luminescence of the beam but spontaneous emission generated in an active region (QW). Would by good if you provide information what was the wavelength of the luminescence ?

- Response:

Thank you for the comment, we clarified that the measured intensity on the CCD bean profiler was spontaneous emission. We understand that referring to "liumenescene" might mean electroluminescence for engineers of analogous semiconductor systems. The spontanous emission spectrum of the active region is very broad given in the spectra figure below. We have added it in figure 3.



- Comment by the Reviewer:

L137 what is quantum well why didn't you explain this when you describe the MECSEL L107 ?

- Response:

We clarified in the text we do not know the specific architecture of the quantum wells and admitted in the Methods section. Sadly, getting structures involves buying them, and the suppliers are protecting their trade secrets.

- Comment by the Reviewer:

L138 "This does give a limit to how dense the pump structures…" I do not understand what you mean "dense" here. May be "This does give a limit for spatial modulation of the pump beam profile " would be better ?

- Response:

Yes, the density was meant as the spatial resolution limit (how many pump peaks and valleys can be observed within the pump area). Thank you very much for the suggestion, we amended the text include the correction.

However, the contrast between intense regions and dark regions is not as clear as on the pump beam itself. This can be due to the diffusion of the carriers in the active areas of quantum wells. This limits the pump structures' density before diffusion equalizes the intensity distribution.

- Comment by the Reviewer:

L140 I do not understand the sentence "Due to the big parameter space various pumping intensity shapes were chosen for evaluation Figure 2."

- Response:

We have rewritten sentences to clarify the reasoning of the chosen masks/beam patterns. Now it reads:

Due to a large selection of possible pumping intensity shapes, some basic intensity distributions were chosen (Figure 2). One way of modifying the pump beam is by removing the central intense region - a "Disk" hologram achieves this. Alternatively, a "Ring" hologram can apodize and remove the edges. Additionally, some periodic structures can be formed by a repeating linear or a 2D varying modulated and not modulated regions.

- Comment by the Reviewer:

L141 "the part that see" should not be used in scientific paper, this is colloquial language which can be used when you talk with your colleagues,. But not written in scientific paper.

L142 "doesn't" should not be used in scientific paper.

- Response:

We thank the Reviewer for the suggestion, we have amended the text.

- Comment by the Reviewer:

L145 "@ 808 nm wavelength" should not be used in scientific paper.

- Response:

We amended the text to read: "we used a hollow fiber-coupled $\lambda = 808$ nm laser diode as the pump source."

- Comment by the Reviewer:

L159 "For a .gif" should not be used in scientific paper.

- Response:

Rephrased the reference to supplementary material, now the text reads:

How the far-field intensity distribution changes from an increase in the pump power is shown in **Supplementary video 1**)

- Comment by the Reviewer:

L166 Sentence "Around this power level, the far field of the generated beam started to have a flatter intensity distribution with a further increase in power giving an intensity dip in the center." Is difficult to understand. Divide it to two. "…..... intensity distribution. The further increase in power gives…"

- Response:

We have splot the sentence in two parts per suggestion.

- Comment by the Reviewer:

L168/169 "This could be the formation of higher-order modes" please show the laser spectra. High order modes will be easily visible in the laser spectra

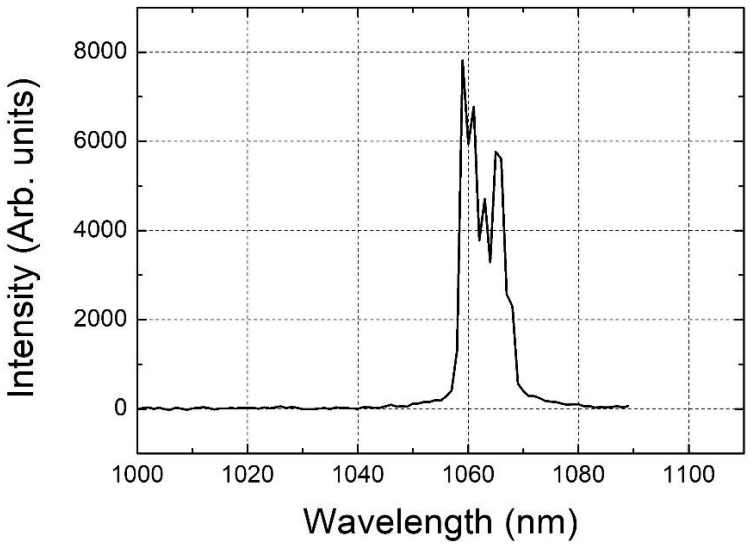
- Response:

The spectra independent on the laser power (except the shift) exhibited multiple peaks due to the heat spreaders having a refractive index mismatch. In particular, we refer to the interface between the heat spreader layer and the active heterostructure. Not a single narrow peak is present in the Fabry-Perot resonator setup. This is a common problem for MECSEL lasers. We mentioned the problem in the text referring to the typical cases, by reference:

D. Priante, M. Zhang, A.R. Albrecht, R. Bek, M. Zimmer, C. Nguyen, D. Follman, G.D. Cole, M. Sheik-Bahae, Demonstration of a 20-W membrane-external-cavity surface-emitting laser for sodium guide star applications, Electron. Lett. 57 (2021) 337–338. https://doi.org/10.1049/ell2.12008.

A. Broda, B. Jezewski, M. Szymanski, J. Muszalski, High-Power 1770 nm Emission of a Membrane External-Cavity Surface-Emitting Laser, IEEE J. Quantum Electron. 57 (2020) 1–6. https://doi.org/10.1109/jqe.2020.3031305.

We have also augmented figure 4 with the following spectra, implicitly indicating that the laser output spectrum is modulated.



- Comment by the Reviewer:

L169 "From the power curves…" change for "From power conversion characteristics (Fig. 4)…"

- Response:

We have amended the text following the suggestion above.

- Comment by the Reviewer:

L186 "has been talked about up until now." should not be used in scientific paper, use "above-mentioned"

- Response:

Thank you for the correction. We amended the text as suggested.

- Comment by the Reviewer:

L231 Another sentences which is difficult to understand. Please add what is in bold "The dominant mechanism for the resonant mode ***formation*** *is defined by the resonator structure/configuration and but not the pump beam structure, but However, resonator modes that don't overlap with the pump beam can't resonate. A change in the pump beam can selectively choose all modes that overlap with the pump beam."*

- Response:

We have made the suggested amendments and improved the readability of the text.

- Comment by the Reviewer:

L236 "…become not a problem…" should not be used in scientific paper because reader do not know what "problems". Be more precise.

- Response:

The wording has been changed to:

Therefore, smaller feature sizes in the pump beam have a small modulation depth and do not influence the laser output.

- Comment by the Reviewer:

There are many more to correct, but do not give up. Correct and send again to high impact factor journal dedicated to optics !

- Response:

We thank the Reviewer for his exceptional effort in offering improvements and positive criticism. We appreciate not only the time investment but encouragement and positive feedback. We have made numerous amendments to the text and tried to mark up and list the major ones in the new versions.