Record of Discussion

*This RoD is a supplement to the original one at the time of application in order to layout discussion to attempt a proof of principle measurement for helium line ratio spectroscopy using the gas feed and optical setup of the GPI diagnostic of Dr. S. Zweben.*

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| **Title of Research Activity discussed:** **Obtain proof of principle for measurement of electron density and temperature by line ratio spectroscopy on helium** | **Collaboration began (mm/yy) or New:**08/2014 |
| **Off-Site Institution:**University of Wisconsin – MadisonDepartment of Engineering Physics | **Discussion Dates**Initiated on: 01-05-2016Completed on: 08-22-2016 (tbd) |
| **Collaboration Principal Researcher:** Name: Oliver SchmitzEmail: oschmitz@wisc.eduTel: +1 608 263 1547Signature: Macintosh HD:Users:schmitz:heimat:persoenliches:lebenslauf:Unterschrift_OS.jpgDate: 08-25-2016 | **On-Site Research Contact:**Name: Rajesh Maingi, Stefan GerhardtEmail: rmaingi@pppl.gov, sgerhard@pppl.govTel: 609-243-3176 or 609-638-3802, 609-243-2823Signature: Date:  |
| **Research Goals:** The research conducted under funding of DoE grant DE-SC00012315 targets on “Control of neutral fueling and helium exhaust to NSTX-U plasmas by means of three-dimensional magnetic control fields”. Within this effort, we proposed, as part of the PhD project of K. Flesch, to work on targeted enhancement of the edge diagnostic suite to support the research focused predominantly on the challenge of understanding the neutral and ionization processes in the outer edge of the plasma. This encompasses two activities. One is improvement of the spectroscopically assisted Penning gauges and the second one is to use existing hardware to obtain a proof of principle for line ratio spectroscopy on helium. This technique allows reconstructing electron density profiles ne(r) and temperature profiles Te(r) with high spatial resolution and a significant time resolution in a continuous way, i.e. for the entire discharge period. Active spectroscopy on helium was deployed with great success for instance at TEXTOR [1]. An enhanced collisional radiative model (CRM) for interpretation at low temperatures and high densities was developed recently [2] by Dr. J. Munoz-Burgos and also benchmarked for application under representative conditions of NSTX-U plasmas [3]. We aim on obtaining first of its kind experimental data of the suitable helium line transitions to deploy this model and establish the method of helium line ratio as a credible and attractive plasma edge diagnostics. The research proposed foresees application of the new CRM, which is ready to go, and is being used on other devices (RFX, Wendelstein 7-X, Asdex-U, protoMPEX) already for data evaluation. We also want to use the opportunity to validate the data obtained from HeLRS against existing diagnostics like divertor probes, Thomson scattering system and others. One element of this project is to deploy a high resolution Echelle spectrometer (/=100.000) available at UW Madison to resolve a spurious C-II line, which is situated close (=0.2nm) to the triplet transition used for the temperature measurement. Deploying this instrument will enable to conduct this measurement in unprecedented spectrographic purity and hence will facilitate in a critical way the test of the CRM.Discussions on-site in the past year have shown that the piggy backing with this activity on the Gas Puff Imaging (GPI) diagnostic, which was developed and is being operated by Dr. S. Zweben is a very feasible route to go. The gas manifold of the GPIU system injects the gas cloud perpendicular to the last closed flux surfaces which is an intrinsic assumption in the HeCRM (forward propagating beam situation). The imaging of the gas cloud on the existing GPI optical head brings the emission from this gas cloud to an intermediate image plane, which is located close to the device on an optical table. This versatile setup facilitates the implementation of the HeLRS observations in two ways.  |
| * **Option 1:** Implement a 10-20% beam splitter in the parallel light path on the optical table and image the light onto a fiber bundle with a set of 12/25 fibers. Two of such fiber bundles each with a length of 35 m and each one encapsulated by a protection housing is available at UW Madison. This fiber bundle the goes into the BES spectrometer room where a table has been reserved to locate the spectrometer. This is the most straight-forward implementation as it only requires setup of the beam splitter optics, pull of the fiber bundle and setup of the spectrometer in the BES room. Only the fiber routing and the eventual fiber installation would need to be done by PPPL engineers and technicians, all other would be done by K. Flesch in collaboration with S. Zweben with support of O. Schmitz. The advantages of this approach is that GPI and HeLRS can be done together (using a 80/20 mixture of H2/He gas), which would for the first time allow to measure ne(r) and Te(r) on a DC time scale (100Hz-1kHZ) at the same time as the density fluctuations from GPI.
* **Option 2:** In case the combination of the two optical systems (GPI and HeLRS) would show to be troublesome in terms of light throughput or in order to be able to increase the time resolution of the HeLRS, it was found feasible to design a new optical head for the reentrant tube of the GPI system. This can be installed w/o breaking the vacuum and hence is an activity, which requires minimal technical support from the PPPL team as long as we stay inside of the reserved room occupation of the present GPI head.

We consider option 2 as a possible next step to enhance the system performance and we want to start with option 1 to obtain a proof of principle. This will allow to test the predictions in [3] and experimentally verify the emission strength and light throughput as a basis to design a dedicated system with possibly an optimized gas feed and a dedicated optical setup so GPI and HeLRS would not need to share the same port. Option 2 is considered as extension and would allow conducting high time resolution measurements (>100kHz) range as proposed by the colleagues from RFX, Padua, Italy. The activity here would lay ground for an extension of the system, which would enable a straight-forward deployment of the RFX hardware (a project discussed at the beginning of 2016).**References**[1] O. Schmitz et al., Plasma. Phys. Control. Fusion **50** (2008) 115004[2] J. Munoz-Burgos, O. Schmitz et al., Phys Plasma. **19** (2012) 012501[3] J. Munoz-Burgos et al., Phys Plasma. **23** (2016) 053302 |
| **UW-Madison Research Tasks (offsite and onsite):**1. Design interface optics to GPI imaging pathway, design and procure system, install
2. Deliver fiber bundle and spec out start and end point
3. Deliver Echelle spectrometer including complete camera and DAQ system, fully setup and ready to go including required alignment equipment (Geissler tube, He/Ne laser), system will be located in UW Madison BES lab (discussed and agreed with D. Smith, R. Fonck)
4. Connect components and commission system
5. Coordinate experiments to obtain data
6. Data analysis using CRM by J. Munoz-Burgos

K. Flesch will do this work in collaboration with Dr. S. Zweben (GPI system) and Dr. J. Munoz-Burgos (CRM). The activity is part of a collaboration on HeLRS involving also Dr. M. Angostini and Dr. P. Scarin from RFX, Padua, Italy. |
| **On-Site Research Support Tasks:**1: Support in interfacing with GPI system and later support to use system (S. Zweben)**Estimated Researcher Effort Required (Man-Months):** 1: < 2 weeks |
| * **On-Site Engineering Support Tasks:**

1: Fiber routing, fiber installation2: Any support on electric supply etc. for Echelle installation (110V power supply)3: Support by CoDaQ team for data implementation into NSTX-U data base**Dependency:** the reactivation of the gas control system for the GPI has to be finished. This is in the actual restart plan and was about to commence before the Pcoil shut down. This needs to be finished as we will rely on the GPI system.**Engineering Effort Required (Man-Months):**1: 1 man months2+3: < 2 weeks**Estimated Hardware Cost Required ($k):** 0 |
| **Collaboration Researcher Questions and Issues:**1. Can the fiber be pulled?
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| **Responses by On-Site Research Contact and Task Manager:**The project has been discussed with Dr. S. Zweben and the two options presented were identified and prioritized as described. Also, we reached out to the RFX colleagues and made sure the attempt made will facilitate their involvement. We aim on setting up a system, which would allow the RFX system to be connected with minimal effort. Matteo and Paolo are o.k. with us pursuing this at this point. |
| **Additional Collaboration Researcher’s Comments (if any):**n/a |
| **Additional On-Site Research Contact and Task Manager Comments (if any):****1)** M. Ono requested this RoD to be written for documentation of the necessary steps |
| **Review and Comment:** **NSTX-U Program Director**Electronic signatureDate: August XX, 2016 | **Review and Comment:** **NSTX-U Project Director, Concurrence**Electronic signature Date: August XX, 2016 |