INVESTMENT IN A COMPACT NEUTRON SOURCE

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Onderzoeks- en Ontwikkelingsbureau
BonPhysics
Research and Investigations B.V.

NORRØNT AS

Executive summary
Business strategy
Objectives & Timeline
Short explanation
About us
Terms & Conditions

EXECUTIVE SUMMARY

This proposal gives an overview of the potential market, needed investments and plan of the proof of principle and further development of a new neutron source. Recent investigations into Rydberg Matter by Prof. L. Holmlid and his collaborators discovered a new technique to produce neutrons. After the realization of a proof of principle, the development of a compact neutron source with a maximum of 1E14 to 1E16 neutrons/second will be possible.

Initially, the MK-I compact neutron source will have an average strength of 1E10 - 1E11 neutrons/second and a cost price of the order of 1 MEuro, depending on its performance. The final target is a neutron source with an average strength of 1E14 neutrons/second for a price of 10 MEuro.

The rising shortage of neutron sources around the world and especially in Europa makes the market for neutron sources continuously growing. The European market size alone will be around 5 sources per year for the coming 5 years, and then 10 sources per year in the following 5 years, and 15 sources per year in the third period of 5 years, after which it probably stabilizes. This is based on the expected live time of the currently available neutron sources. Hence, the estimated turnover in Europe starts with 50 MEuro/year and grows after 15 years to 150 MEuro/year. The worldwide market is a multitude of this.

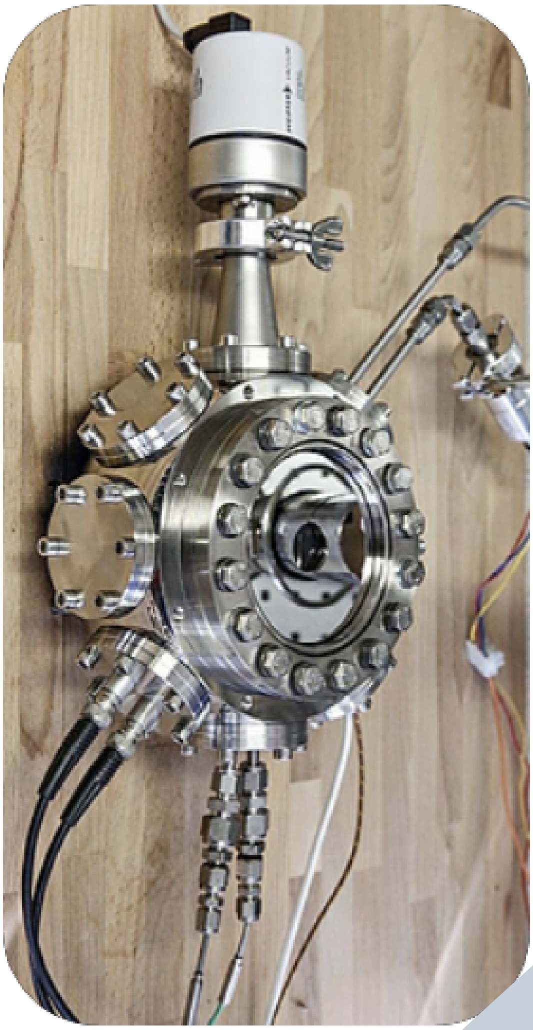
BUSINESS STRATEGY

Currently, the Norrønt AS neutron source is in the proof-of-principle phase, and the source strength is estimated to be of the order of 1-10 MBq.

Until now, the energy and spatial distribution of the emitted neutron radiation is largely unknown. Further, the source strength is unstable and quite unpredictable. For an optimal and commercial source design the precise production mechanism must be known, and the strength should become stable.

This calls for research in the fundamental properties of the source and the development of stable methods to control the source strength.

Finally, because the neutron source needs to meet customer expectations, it is important to incorporate their expectations in the process of development.



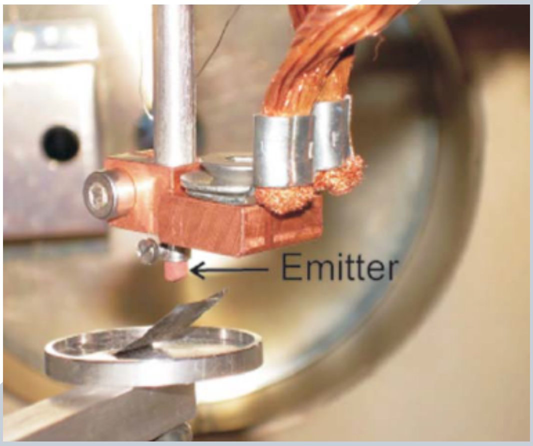


Photo of source container vacuum vessel (Top) and prototype of Rydberg matter source (Bottom)

OBJECTIVES

1. **Source optimization:** As the neutrons are produced from muons, first production must be optimized and the muon-source needs to be stable and predictable. Therefore, the ultra-dense hydrogen production, the excitation mechanisms and the detection mechanisms will be improved.
2. **Radiation hazards:** The identification of radiation hazards (based on MK-I type of neutron source), both during operation of the neutron source and non-operation and dismantling. These radiation hazards need to be compared to the acceptable hazards for occupation related activities and for the general public. If these hazards are measured significantly, they must be defined and the source should be designed in a way that no relevant hazards remain.
3. **Prototype MK-I:** A prototype for the neutron source MK-I must be built to enable the evaluation of the source performance and the research path tests.
4. **Energy distribution tests:** Experiment(s) to test the neutron energy distribution must be designed and executed.
5. **Direction distribution tests:** Experiment(s) to test the neutron direction distribution must be designed and executed.
6. **Pulse time-structure tests:** Experiment(s) to test the time-structure of the neutron pulse must be designed and executed.
7. **Market awareness:** To be market - aware, visits will be paid to potential customers, market survey will be done using questionnaires, and we will contribute to conferences.

TIMELINE

YEAR 1 YEAR 2 YEAR 3 YEAR 4

CONCEPTUAL DESIGN

TESTING

DETAILED DESIGN

CONSTRUCTION

OPERATION

CLOSURE

A conceptual design is developed, to explore all opportunities.

The instrument is tested and all parameters are fine tuned to reach optimal performance.

The definitive set up and requirements for the equipment and tests are established.

Needed equipment is purchased or manu-factured, and components are put together.

Operation during normal use is monitored.

Result disseminated to stake holders and future plans.

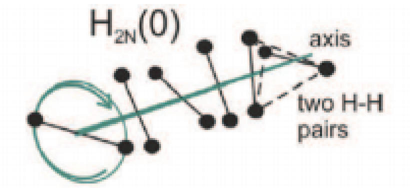
SHORT EXPLANATION

Neutrons are produced by a fusion reaction between two nuclei of hydrogen isotopes. This reaction is initiated by a catalyzing reaction with negatively charged muons, for example:

$$\mu^- + p \rightarrow n + \nu_\mu$$

These reactions are well known, as muon catalyzed fusion. They can occur in all hydrogen containing materials, that are penetrated by muon particle radiation. Thus, muons are utilized to produce the neutrons.

The source of muons is formed by a unique compact matter also existing of hydrogen isotopes. Hydrogen gas or Deuterium gas can both be utilized as source. The structure of this matter can be visualized in the following, semi-linear geometrical, figure:



This unique type of matter is named 'Rydberg matter', and derives from desorption of hydrogen of a catalyst's surface. A functioning catalyst can be industrially obtained. The matter can be gathered in a reservoir. Utilizing an excitation mechanism (laser pulse) the matter can be brought into resonance. During this process, the probability on interaction between different nuclei; therefore, the production of muons, increases greatly. However, it is not known exactly, how muons are produced.

It is known, from literature that the fusion yield of a laser pulse on molecular clusters depends on the energy of the laser pulse and the size of the clusters. The bigger the size of the cluster, the smaller the amount of energy needed of the laser pulse for an equal yield. Moreover, the yield is greatly dependent from the exact composition and structure of the clusters.
This might be the reason why 'Rydberg matter' only requires a small amount of energy, since the clusters can become very large.

Other implementation possibilities of the muon source are: radiography, isotope production, analyzes of elements, and transmutation of radioactive waste.

ABOUT US

Dag H. Zeiner-Gundersen (left)

30 years of international management and engineering experience from renewable energy sector and oil & gas industry. Specialist in general physics, comprehensive work in condensed hydrogen and nuclear physics for more than 10 years, instrumentation Nano engineering, turbine technology and subsea technology.

Sindre Zeiner-Gundersen (right)

PhD student at the University of Iceland. Works at the characterization of the required source material (Rydberg matter) and its interactions.

Victor de Haan

Victor de Haan received the Bachelors degree in physics from the Hoger Technische School, Dordrecht, in 1986, and the Master's and the Ph.D. degrees from Delft University of Technology, Delft, The Netherlands, in 1991 and 1995, respectively. He is currently the Director of BonPhysics BV, where he specialized in electromagnetic and neutron radiation research.

TERMS & CONDITIONS

More information about the scope of work and deliverables can be found in the project proposal, on the website of BonPhysics B.V., here.
(or use this address: *http://bonphysics.nl/wp-content/uploads/2020/01/BONP1183r4.pdf*)

There is a collaboration agreement between Norront AS and Bonphysics B.V. for the initiation of this project. The final terms and conditions are to be negotiated between investment partners.

All knowledge shared in this brochure is determined confidential and not transferable to third parties, except with a written consent of Norront AS and Bonphysics B.V..