Proposed NIST Neutron Source User Facility

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INTRODUCTION

The NIST Center for Neutron Research (NCNR) serves as one of the nation's primary resources for research using neutron techniques. The National Bureau of Standards Reactor (NBSR) at the NCNR provides a safe and reliable neutron source for the thousands of visiting U.S. and international researchers annually. The NBSR has a long history of successful operation since its startup in 1967 [1]. It is licensed to operate by the U.S. Nuclear Regulatory Commission until 2029 at which point it will be relicensed. It is now one of only two major steady-state neutron scattering facilities in the U.S.

The NCNR has a long-standing reputation for scientific productivity, as measured by the abundance of scientific publications and research participants. The measurement facilities are perennially over-subscribed with a continually increasing demand from the scientific community. There are also increasing maintenance demands associated with aging NBSR reactor systems and components. To address these issues in the longer term and to accommodate novel scientific instruments, a new state-of-the-art research reactor is proposed for the NCNR. The new reactor (NIST Neutron Source, or NNS) will be tailored primarily for neutron science involving thermal and cold neutron beams. It will provide thermal neutron beams directly and cold neutron beams via cryogenically-cooled moderator inserts (Cold Neutron Sources, or CNSs). The cold neutron beams are used mainly by instruments exploiting neutrons with energies less than about 5 meV or DeBroglie wavelengths, λ, greater than about 0.4 nm. The proposed siting of the NNS adjacent to the NBSR would allow the latter to continue operation during the NNS construction and to share existing NCNR infrastructure and personnel resources. At initial startup (commissioning), the NNS should deliver equivalent measurement capabilities to the existing NBSR neutron source. Once at full capacity, the facility should significantly alleviate the current over-subscription of scientific instruments.

The NNS's cold and thermal beam intensity increases, combined with an increased number of instruments and a focus on reduced background radiation contamination will revolutionize the impact of NCNR. Not only will the NNS significantly alleviate overdemand, but experience shows that these improvements will lead to the emergence of new science. For example, due to improvements in neutron instrumentation, neutron beam optics, and two CNS upgrades, the NCNR performs experiments today not thought possible in 1987 when the first (D_2O ice) CNS was commissioned [2].

Cold Neutron Beams and Cold Neutron Guide Network

The NNS reactor core and CNS design prioritizes a significant increase in the useable cold neutron beam intensity over the NBSR. Extensive simulations have been performed [3] which compare the NBSR planned Unit 3 liquid deuterium (LD_2) CNS with the NNS dual LD_2 CNSs. The initial results imply a total cold neutron (λ > 0.4 nm) current gain at the guide entrances ranging between 4.8 and 6.4, depending on the choice of guide entrance cross-section. There are indications that these gain factors could increase with further optimization of the CNS dimensions. The cold neutron gain at the instruments may be further enhanced over that available at the guide entrances by designing the intervening neutron optics for improved transmission within the specific beam area, beam divergence, and bandwidth used by the instruments. This concept has been referred to as improving the brilliance transfer [4]. Optimizing brilliance transfer for a specific instrument-sample configuration minimizes those neutrons that either cannot be transmitted onto the sample and/or cannot be measured as a result of their incident trajectory. Such neutrons only contribute to unwanted background counts.

An initially-proposed suite of cold neutron instruments may be classified as shown in Figure 1 for Groups 1 and 2 on the north side and in Figure 2 for Groups 3 and 4 on the south side. All neutron guides shown are technically feasible and to scale. Each has a high simulated cold neutron transmission using currently-available supermirror coatings combined with a low fast-neutron and gamma-ray transmission (due to the guide curvature). Definitions of the instruments represented in the figures and options are summarized in Table 1. More details are given in Ref. [3]. Additional end-guide positions (not shown in these figures) can be created with benders on guides whose end-position instruments do not require the full beam height (e.g., SANS instruments).

Monochromatic beam positions may be created on the sides of the longer guides and on outer guides where the full beam area can be used in most cases with little perturbation to downstream instruments. It is recognized that as construction proceeds, groups of prospective facility users will be convened to finalize and optimize the initial instrument suite according to scientific priorities and needs.

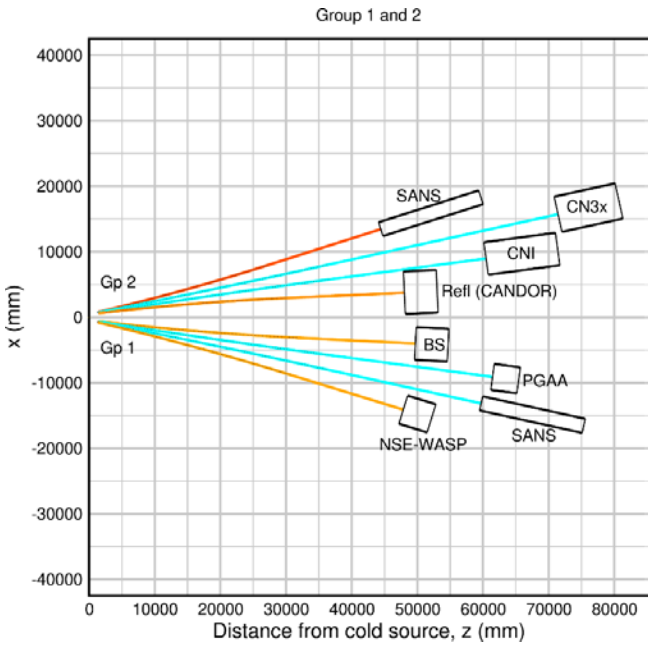

Figure 1. Possible Instrument Layout for Groups 1 and 2 (from Ref. [3]).

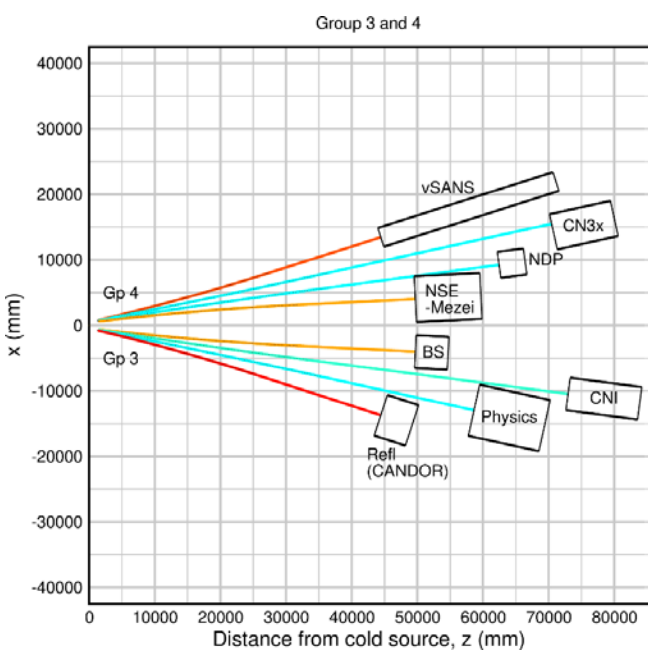

Figure 2 Possible Instrument Layout for Groups 3 and 4 (from Ref. [3]).

Table 1 Proposed cold neutron instruments for the guide halls. More than 16 end-positions can be created with additional side positions on bender devices.

Instrument type	Total Number	End position
Small-Angle Neutron Scattering (SANS)	2-3	YES
Reflectometer (CANDOR type)	2	YES
Cold Neutron Imaging (CNI)	2	YES
Cold 3-Axis (CN3X)	2	YES
Backscattering (BS)	2	YES/NO?
Neutron Spin-Echo (NSE) (Mezei-type)	1	YES
Neutron Spin-Echo (NSE) (WASP type)	1	YES
High current physics experimental position (Physics)	1	YES
Prompt Gamma Activation Analysis (PGAA)	1	YES
Neutron Depth Profiling (NDP)	1	YES
Materials Diffractometer ($\lambda >$ 0.3 nm)?	1?	YES
Interferometer	1?	NO
Monochromatic Physical Measurements Laboratory (PML) positions	2-3?	NO
Miscellaneous monochromatic/ test positions	2-3?	NO
Very Small-Angle Neutron Scattering (vSANS)	1	YES
TOTAL	22-25	16-18

Thermal Instruments

The shorter wavelengths (λ ~ 0.1 nm) and higher energies (~ 0.025 eV) of thermal neutrons are essential for a certain class of experiments using a variety of scattering and imaging methods. Instruments being considered for use on the thermal beams, along with their abbreviations, are listed in Table 2. A preliminary layout for the thermal beam instruments is shown in Figure 3. Accommodating a possible suite of nine thermal beam instruments at the NNS will likely require several instruments being located further from the core on neutron guides. These may be straight or curved multichannel "bender" devices. As for the cold neutron instruments, the thermal neutron instrument suite will be finalized in collaboration with the user community.

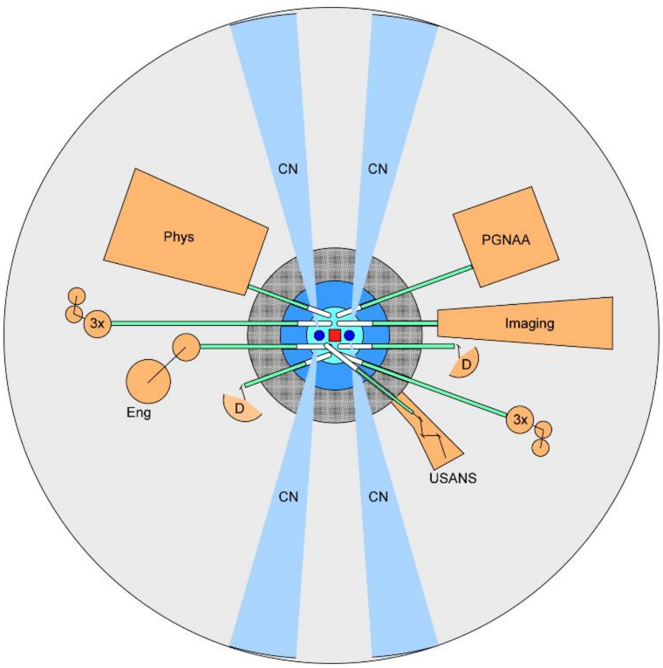

Figure 3: Beam guide configuration and thermal instruments.

Table 2. Instruments being considered for the NNS thermal beams.

Instrument Type	Abbreviation
Prompt Gamma Neutron Activation Analysis	PGNAA
Neutron Microscope	Imaging
High-Resolution powder diffractometer	D
Triple Axis Spectrometer	3X
Ultra-Small Angle Neutron Scattering	USANS
High Throughput Fast Powder Diffractometer	D
White Beam Engineering Diffractometer (with CANDOR-type detector)	ENG
High Current Physics Experimental Position	PHYS

The NNS will produce a significant gain in thermal neutron flux by having a compact core design [5]. The NBSR, which by contrast has a larger cross-sectional area, has a peak unperturbed thermal neutron flux in the reflector of about 2×10^{14} $cm^{-2}s^{-1}$ at a 20 MW power level. The NNS core will produce a minimum peak unperturbed thermal neutron flux in the reflector of about 5×10^{14} $cm^{-2}s^{-1}$ at 20 MW. Simulations [6] indicate that at least a factor 2 increase in the thermal neutron Maxwellian brightness is anticipated through the thermal beam tubes with respect to the NBSR.

DISCUSSION

By having two major CNSs the NNS increases cold neutron guide access with a broad suite of cold neutron instruments and an increased number of cold-neutron end-stations. This, along with the high brightness of dual CNSs creates a significant boost in the potential cold neutron experimental output over what is currently possible at the NCNR. The simulated cold neutron current gain at the guide entrances of at least about a factor 5 may be further enhanced at the instruments via state-of-the-art neutron optics. The emphasis on enhancing both signal and signal-to-noise ratio will lead to improved data quality as well as greater experimental throughput, rendering previously impossible measurements of subtle phenomena possible.

The thermal instruments at the NNS should benefit from at least a doubling of the Maxwellian brightness and, unlike the current NBSR configuration, may take advantage of advanced beam guide technology using high critical reflection angle supermirror technology. This allows instrumentation to be placed further from the reactor face. This also enhances performance due to lower background radiation as well as potentially reducing beam-dependent background by limiting the transmission of neutrons outside of the usable divergence range of the instrument. It will also facilitate instrument layout and access.

DISCLAIMER

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