Tests of a Prototype Large-Bore, Low-Power $2 \leftrightarrow 4$ RF Transition Unit

R.S. Raymond, Randall Lab of Physics
University of Michigan, Ann Arbor, MI 48109
September 18, 1997

Abstract. The Michigan ultra-cold polarized hydrogen jet requires a $2 \leftrightarrow 4$ RF transition unit with a large bore, low power input for cryogenic operation, and a static magnetic field parallel to the atomic beam. The prototype unit has a cylindrical RF cavity with clear bore of 7 cm, loaded with a dielectric ring. Transition efficiency has been measured using a maser run in transient mode, by observing free induction decay. In tests on a room-temperature polarized beam, for static fields of under 100 G, we have measured efficiencies of 95% with less than 100 mW of RF power.
This work is supported by a grant from the U.S. Department of Energy.

The Michigan ultra-cold polarized hydrogen jet[1] requires a hydrogen $2 \leftrightarrow 4$ RF transition unit with a large-bore, low power input for cryogenic operation, and a static (and therefore RF) magnetic field parallel to the beam direction. To meet these novel requirements we have built and tested a room-temperature prototype cavity consisting of a metal cylinder with end plates, loaded with a dielectric ceramic ring. The ring is in the cylinder midplane. The atomic beam passes through large holes in the end plates and along the axis of the cylinder and ring. RF power is fed in via a small coupling loop on one side of the cavity, in the midplane and outside of the ceramic ring. The desired mode, $TE_{01\delta}$, gives an axial RF magnetic field.

The prototype cavity uses a ceramic ring 11 cm O.D., 7.5 cm I.D. and 2.2 cm thick, with a dielectric constant of 13.9.[2] Metal parts of the prototype cavity are aluminum, with the cylinder 15.24 cm I.D., the holes in the end plates 7 cm I.D., and the inside length, for resonant frequencies of about 1425 MHz, about 5 cm. Teflon rings hold the ceramic ring centered in the cylinder. The Q value for the $TE_{01\delta}$ mode is about 7000.

For room-temperature beam tests of the prototype cavity we built a segmented solenoid allowing independent variation of the central field and the

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1) V.G. Luppov, Ultra-Cold Methods for Polarized Atomic Hydrogen, this conference
2) The ceramic is SMAT-14, from Transtech, Inc.

CP421, *Polarized Gas Targets and Polarized Beams:* Seventh International Workshop
edited by Roy J. Holt and Michael A. Miller

axial field gradient. The assembled unit was then mounted between a small ground-state atomic beam source and a maser polarimeter, with a quartz tube through the transition unit to carry the room-temperature beam.

The maser consists of a Teflon-coated quartz bulb inside a loaded high-Q cavity tuned to 1420.4 MHz. Coils inside magnetic shields provide a uniform field of .1 mT over the bulb. For use as a polarimeter the maser is run in the transient mode, with the beam intensity below the threshold for self masing. We excite the cavity with a short pulse of RF power and record the resulting signal from free induction decay. The integral of this signal over a fixed time period is proportional to the difference in numbers of atoms in states 2 and 4. To measure the transition efficiency of the transition unit we measure the integrated signals, S, with RF power to the transition unit on and off, and a background, B. The transition efficiency, E, is

$$E = \frac{1}{2}\left(1 \pm \frac{S_{on} - B}{S_{off} - B}\right) \tag{1}$$

The + and - are for efficiencies greater and less than 50% respectively; there is a 180° phase change of the decay signal at 50% efficiency. S and B for these tests were typically 5 and .3 (arbitrary units), respectively. By moving the cavity and plates we could vary the resonant frequency, and so were able to measure the transition efficiency for static fields from 1.8 to 20 mT. Maximum efficiencies for each field are listed in Table 1.

TABLE 1.

RESULTS

STATIC FIELD (mT)	TRANSITION EFFICIENCY
20.0	75%
15.0	88%
10.5	92%
8.0	94%
5.6	95%
2.6	95%
1.8	95%

At low fields, less than 100 mW of RF power were required for efficiencies of over 95%. At higher fields, the efficiency was limited by the RF power available, about 300 mW.

We are continuing studies of the prototype and beginning the design of a cryogenic version. Tests indicate that there are no large changes in the characteristics of the ceramic at low temperatures, but support and cooling of the ring pose significant engineering challenges.

This work was supported by the U.S. D.O.E.