particle model. In our opinion the observed phenomenon is caused by residual plasma discharge generated in the system, resulting in the increase of the extraction efficiency.

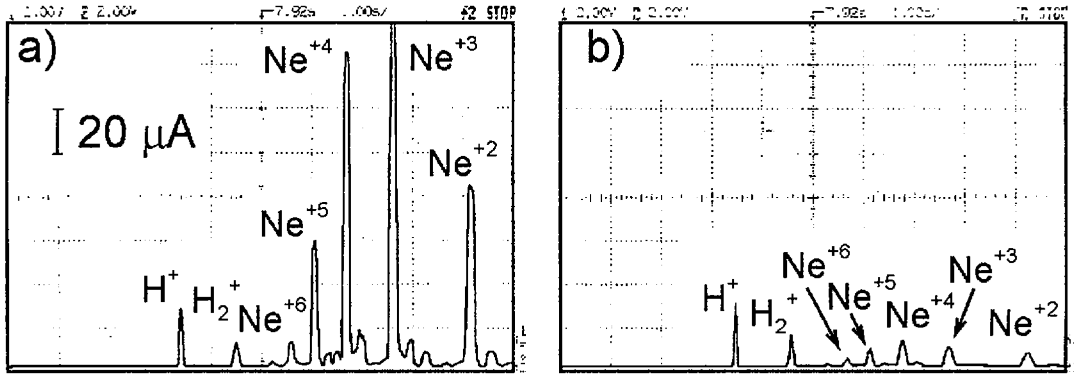

Fig.3. Ne beam spectrum: a) Einzel lens voltage 770 V b) Einzel lens voltage 640 V

Additional remarks:

- a voltage of a few tenths Volts on electrode I or III (Fig.1) decreases the ion beam current from few percent up to 40%. The better the vacuum and the higher charge state, the weaker effect is observed. The influence of the electrode III on the ion beam current is stronger than that of the I-st one. Such a strong effect caused by low voltage cannot be explained by improvement of optical properties of the extraction system.
- a gas mixing effect occurs when adding the buffering gas not only to the plasma chamber, but also to the extraction chamber. Probably this effect is related to vacuum level in the extraction chamber.

4. Amplitude and Phase Regulation of the RF Cavities

PL0400934

J.Miszczak, Z.Kruszyński, M.Sobolewski, B.Daniel

Until the end of year 2002 the cyclotron's main RF cavities operated in open loop mode i.e. without circuitry comparing the dee voltage with the desired value and making a correction accordingly. In order to improve performance of the cyclotron it was decided to build two amplitude control loops (one for each of the resonators) and one phase loop. The loops are analog, with a computer controlling the setpoints, loop mode, and reading back values for display for the operator.

The amplitude loop is pretty straightforward with a peak detector, a PID regulator, and an amplitude modulator. The amplitude detectors operate with large input signals, so with the use of germanium diodes, there is no problem with nonlinearity of the diodes. The PID regulators are really a PI, in order to decrease the burden placed on the RF amplifiers during RF-on transients. The loop gain K, and Ti time constant are set in hardware. The amplitude modulators are build with the EL4094 chips from Elantec company. They are sold as "video gain control/faders" for use in TV broadcast circuits, but they make very good and inexpensive amplitude modulators usable from DC to 20MHz.

The main design challenge was the phase loop. It has to operate with RF frequencies spanning from 12.5MHz to 19.5MHz, which makes it difficult to build a linear phase modulator, and a pulsed mode requires a phase detector capable of dealing with RF-off periods.

The design of the phase modulator builds upon an idea of "phase sequencing network". This is a network of resistors and capacitors, which outputs a set of quadrature signals when fed with phase and anti-phase input signal, with only minimal phase error over wide span of input frequencies . The quadrature signals are combined in an I/Q type of modulator, which is followed by an AGC stage so only phase modulation remains. The output of the modulator are two RF signals - one is the reference (to resonator A), and the second can be shifted by +/- 40 degrees with respect to the reference.

The phase detector is classic, with the monolithic MC12040 ECL phase-frequency detector from Motorola. When the RF is off and during RF-on transients the phase detector is switched off the loop. This prevents false phase readings reach the phase PID regulator. As with amplitude loop, regulator's parameters are set in hardware.

The amplitude and phase control loops were successfully commissioned in the very beginning of 2003. It was observed almost immediately that the loops significantly improved intensity and stability of the beam.

5. Beam energy measurement using the time-of-flight method

PL0400935

M. Sobolewski, J. Miszczak, J. Sura

The time-of-flight (TOF) system of beam energy measurement, presented in the HIL Annual Report 2001, has been completed and routinely used. Three cylindrical pick-up probes were installed in the C2 beam line. The probes have the inner diameter of 58mm and the length 30mm, except for the N1, which is only 15mm long (for spill beam reason). The probes are shielded by diaphragms of diameter 52mm. The bases between probes are equal: between N1and N2 - 2.7375m and between N2 and N3 - 6.5300m. The probes N1 and N2 are being used to rough estimate of the beam energy in the common line of the beam garden. The N2,N3 are used to precise energy measurement in the beam line C2. The clock-like signals induced by the beam bunches are amplified by 100dB and afterwards differentiated. The time of flight is measured between the zero-points of the differentiated clock-like pulses using the digital Tektronix TDS 640A oscilloscope (with time resolution of 50ps).

The minimum average beam current, which can be measured with reasonable signal-to-noise ratio is around 50nA. The accuracy of medium energy determination proved to be better than 0.5%. This value has been checked in numerous experiments, where the energy could be independently measured (e.g. with beams of ions: $^{14}N^{3+}$, $^{20}Ne^{3+}$, $^{20}Ne^{4+}$, $^{40}Ar^{7+}$, $^{19}F^{4+}$).

A detailed description of the HIL TOF system is given in an internal report (in preparation).

6. A new radiological safety interlock system

PL0400936

T.Bracha

No accelerator facility in the world can operate without radiological safety interlock system. Detailed operation of such a system is a subject of national and international regulations. The Warsaw cyclotron operated with a custom made, relay based, interlock system. The system was inflexible and rather inconvenient to use. It was decided to replace the interlock system with a new, programmable one. The new system was designed and built in-house, using PLC controllers manufactured by Siemens. The control program for the PLC was developed and tested on a PC computer and then downloaded to the PLC. The development environment called LEGO is very easy to use, with nice graphic user interface.

The new control unit is located in the cyclotron's main control room, and is connected to limit switches, indicator lamps, panic buttons etc. located elsewhere in the cyclotron building. It