Using Mass-flow controllers for obtaining extremely stable ECR ion source beams

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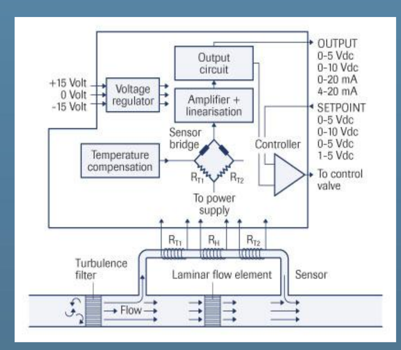
ABSTRACT :

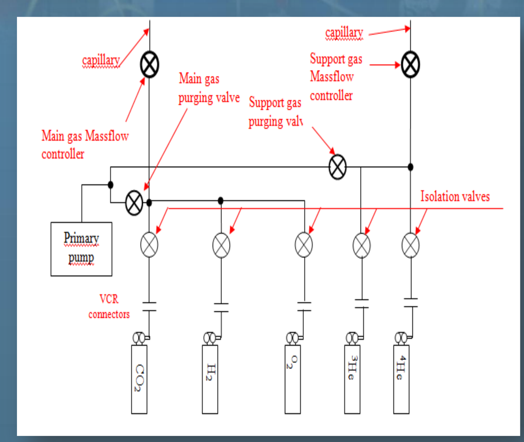
Beam stability and reproducibility is of paramount importance in applications requiring precise control of implanted radiation dose, like in the case of Hadrontherapy.
The beam intensity over several weeks or months should be kept constant. Moreover, the timing for changing the nature of the beam and, as a consequence, the tuning of the source should be minimized. Standard valves usually used in conjunction of ECR ion sources have the disadvantage of controlling the conductance, which can vary significantly with external conditions, like ambient temperature and inlet pressure of the gas.
The use of flow controllers is the natural way for avoiding these external constraints. In this contribution we present the results obtained using a new model of Mass-flow controller in the Supernanogan[3] source, for production of C^{4+} and $H_3^{\ +}$ beams.
Extremely stable beams (+/- 2.5%) without retuning of the source over several weeks can be obtained. The reproducibility of the source tuning parameters can also be demonstrated.

GAS SYSTEM

The gas system is designed for an automatic control of switching and regulating gas without operators intervention.

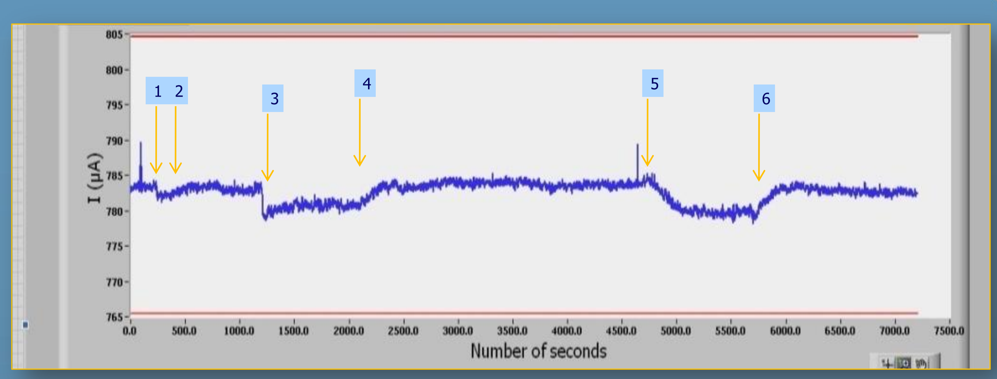


Principle of the Mass-Flow Controller from Bronkhorst(tm)

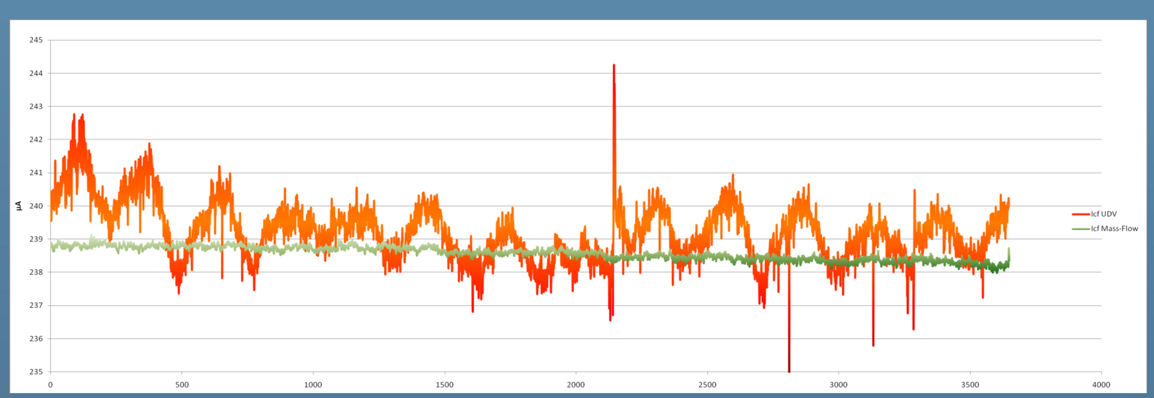


System reproducibility when changing the flow

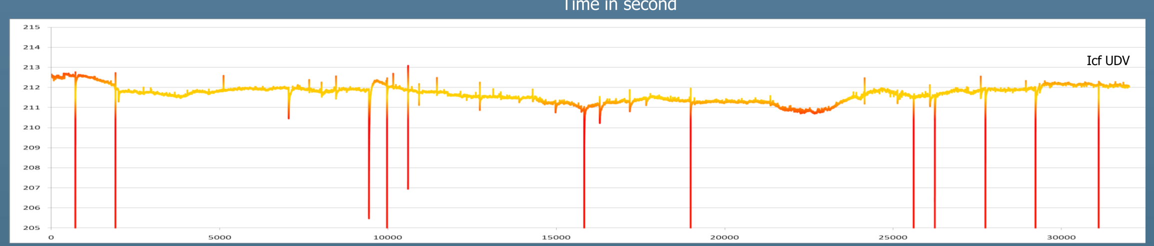
In order to demonstrate the reproducibility of the system, we changed the flow of the He gas and came back to the original value. There is no hysteresis effect like in UDV dosing valve and the reactivity is <5s.
The flow can be adjust to the set point with a ramp (arrows 2,4,5,6) or without (arrows 1,3) .
We changed the flow with a step= 0.5% (of the max aperture) on arrow 1 and 2.
The ion source is insensitive to changes smaller than 0.5% for this tuning.
We changed the flow with a step=+/-1.25% on arrows 3,4 and 5,6. The ion beam current is restored.



Beam evolution during long term period



This graphic shows the evolution of the beam during 1 hour using UDV valves and MassFlow Controller
The big wave observed is due to the start and stop of the air-conditioning system in our test-room.
The Mass-flow is insensitive to low variation of temperature which is a requirement for Hadrontherapy[1].
The mean noise is lower with MassFlow, the reason is the following:
The gas mixing rate between support and main gas is maintained constant with the two Mass Flow while it can change with UDV140

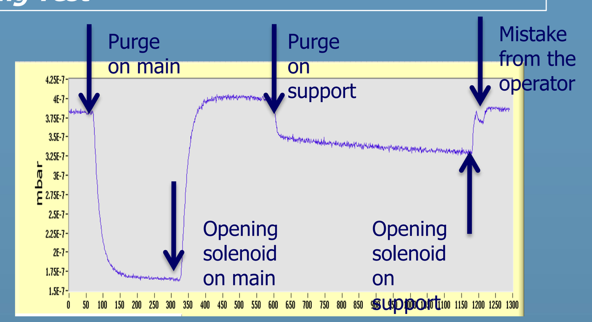


This graphic shows the evolution of the beam during 10 hours using UDV valves. The test with Mass-flow is in progress at Marburg's Hadrontherapy Center.

Closing Test

A test was proceeded to check the closing of mass flow. The gas panel was purged (solenoid valve closed) and we opened the solenoid valve on main gas. The same procedure was done on the support gas (see gas diagram on the top figure). The effect is not exactly the same between the main and the support due to different pipe volumes.

The conclusion is that it is not possible to closed completely the mass-flow controllers.

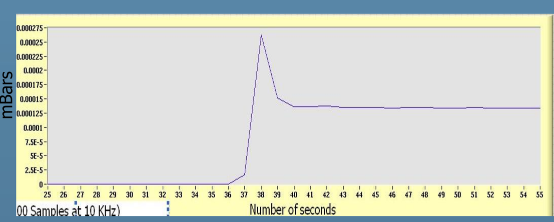


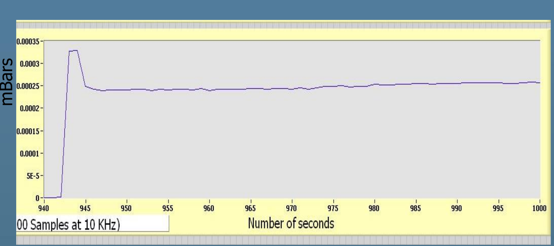
Overshoot with big varation of the gas flow

In order to know the behavior of the mass-flow when you make a big variation of the flow, a test was done from 0 to 50 % of full aperture and another from 0 to 100%.
The rotation of the turbo pump was set to 66% of the max speed in this test.

The overshoot goes to 2,6 10-4 mBar for 1,5 10-4 mBar for the first test.
The overshoot goes to 3.33 10-4 mBar for 2,5 10-4 mBar for the first test.

This transient period takes about 5s.

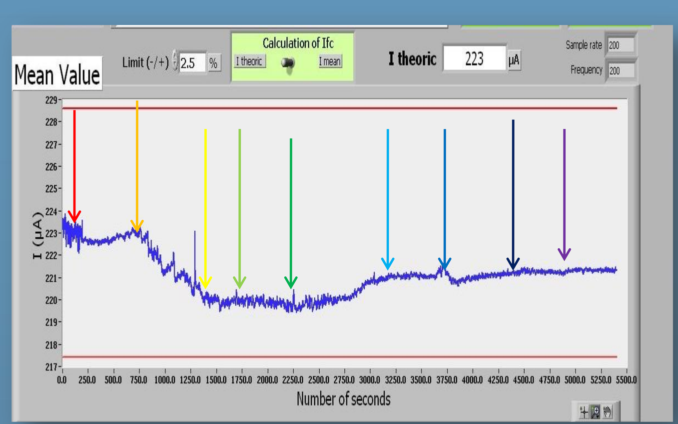


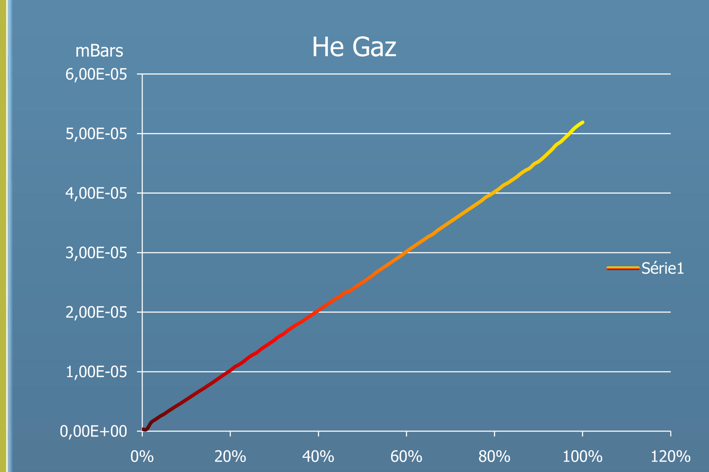


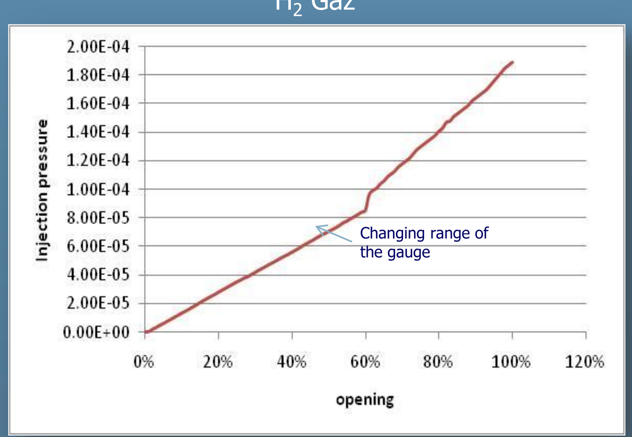
System reactivity with sudden temperature changes

Time (s)	Temperature
0	22.4°C (start stability file)
600	22.4°C (start air cooler, set to 16°C)
1200	16.6°C
1800	15.1°C
2400	14.4°C (stop air cooler)
3000	16.6°C
3600	18.2°C
4200	20.1°C
4800	20.8°C
5400	21.2°C

We see that the Mass-flow is only sensitive to very high variation of temperature.
Nevertheless , it stays under the 2.5% of the limit (red line) .







A calibration has been done on 2 different gases in order to investigate the behavior of the valve and its resolution.
The step at 60% for H_2 is due to the range of the IP monitor (10E-5 to 10E-4) so it changes calibration.
The opening is linear and the step resolution is around 1.4E-7 mbars.
The response time is less than 3s for small step.
The turbo Pump at the injection is set to 100% of its max speed.

Next Step : Smart Bench for ECR source (Automatic Source)

• The use of UDV valve provided a good stability[2]

but the main default in this system are :

• High sensibility to temperature variation.
• Hysterisis shape of valve electrical response.

The main issue for having a stable beam from an ECR Ion source is the precise control of the gas flow.

Massflow Controllers solve the problems.

Today, we can consider building a smart system for producing Ion beam dedicated to HadronTherapy with :

• High reproducibility of beam parameter.
• Insensibility to low temperature variation.
• Stable beam with a good Emittance during several weeks
• Without any intervention of operators.

The future system will allow the operator to select the type of Ion (example C^{4+}) and the intensity (200 μAe). The system will self-adjust Gas, Focus, Puller, RF tuner, Frequency and RF power parameters for reaching the desired values after several minutes.

References

1: J.Lettry,L.Penescu, J. Wallner, and E. Sargsyan, Rev. Sci. Instr. 81 (2010) 02A328
2: T.Winkelmann, R. Cee, T. Haberer, B. Nass, and A. Peters , Rev. Sci. Instr. 81 (2010) 02A311
3: C.Bieth, Nucleonika 48 (2003) S93

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