Developments towards advanced scanning in the Gantry 2 test area at PSI

PTCOG 46 Zibo

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PROSCAN project

Medical program at PSI with dedicated accelerator

- Superconducting cyclotron
- 250 MeV protons
- Deflector plate for fast intensity modulation (50 μs)

Patient area
PROSCAN project

Restarted patient treatments in Feb. 2007
Gantry 2 test area

Operated in 2006 at future coupling point to Gantry 2

- COMET commissioning
- Test and develop therapy control system
Experimental layout: a simplified setup of Gantry 2

Sweeper magnets

- T-direction 2.2 cm / ms
- U-direction 0.5 cm / ms

Spot size ~1 cm (2σ)

Scintillating foil with CCD camera to observe lateral spot position and intensity

Ionisation chamber to control dose

Plexiglas stack to measure depth dose
**Beamline for fast energy selection**

**Goal:**
- Fast energy change with same intensity

**Problem:**
- Transmission of degrader is highly energy dependent (~1% for 100 MeV)
- Inserting mechanical collimators is slow

**Solution:**
- Defocus beam (electrically) with quadrupoles on a collimator to compensate intensity losses
- Change energy in typical steps of 3 MeV within 90 ms (with Gantry 2 90° bending magnet ~150 ms)

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Beamline for transport *and* energy selection

Degrader: graphite wedge to reduce initial proton energy of 250 MeV

No range shifter on Gantry 2: Beamline magnets must be set for each new energy

Comet to Gantry 1

Collimator

Gantry 2 test area

Degrader

to Gantry 1
Spot scanning mode

Variable energy in ~ 3 MeV steps,
lateral spot grid: 5 mm
1 gray in a 8 x 8 x 8 cm³ cube
in 40 s (~0.3 nA)

Dead time 15%, will increase with
integrated verification system

Good homogeneity and
reproducibility (~1%)

Calculation describes data well
Therapy Control System TCS

Therapy Control System is based on Gantry 1 concept (divided delivery and verification part).

For the test area only the delivery part was implemented.

Scanning Delivery System: Dynamic actuators

- Sweeper magnets (position)
- Deflector plate (beam intensity)

are interpolated in real-time from delivery tables with a timing resolution of 10 μs.
Continuous line scanning

Orthogonal line scanning at maximum magnetic speed (meander pattern)

Current for sweeper magnets are interpolated from delivery tables

Next step: Reduce grid size to get homogenous dose distribution

Use vertical deflector to mask reversal points
Continuous line scanning II

Use line scanning to build cubic dose distribution:

- 75 ms for a single 6 x 8 cm\(^2\) plane
- 129 repetitions (highest energy)
- In total 494 energy layers

1 gray in a 6 x 8 x 8 cm\(^3\) cube in 50 s (~0.3 nA)

Dead time 48%, potential to optimise (beam path, mask edges)

Good homogeneity even dose was not controlled (beam fluctuation)
“Simulated Scattering” as an optional mode

Use a fast scanning beam to paint a homogenous lateral dose distribution for one energy layer.

A collimator and / or compensator can be used to conform the dose.

Goal: Show that a scanning system can simulate scattering.
Intensity modulated lines and arbitrary curves

Intensity modulated line (15 cm) painted in 30 ms using the vertical deflector to change beam intensity within 50 µs.

PSI logo painted in 80 ms.
Gantry 2: a system with different scanning options

A scanning gantry with different scan modes:

- Spot scanning
- Line scanning
  - Intensity modulated TV-scan
  - Simulated scattering
- Contour scanning

Which mode? Answer from clinical needs; may depend on medical situation

Aim: Treatment of moving tumours with scanning
Conclusion

• A test area was operated during the commissioning of the new COMET accelerator

• Developed and tested a prototype therapy control system for Gantry 2
  • Implemented spot scanning mode
  • Tested line scanning (TV mode, simulated scattering)
  • Explored advanced scanning modes (intensity modulation, arbitrary contours)

• Experience from test area is transferred to Gantry 2; Gantry 2 will be a machine providing these different modes
Outlook

Test area was closed at the end 2006 to connect Gantry 2 to beam line, developments will restart on the gantry itself

First beam on Gantry 2 is expected by the end of 2007

Developments on Therapy Control System

• Integration of the verification system

Adaptation treatment planning