

Intensity Modulated Radiation Therapy

Types of IMRT Delivery

Chester Ramsey, Ph.D.

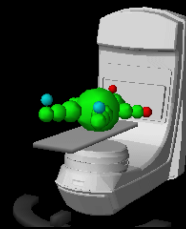
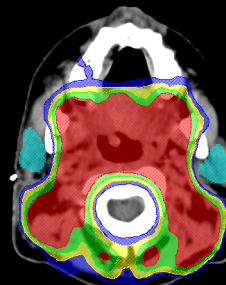
Chief Physicist

Thompson Cancer Survival Center

IMRT Delivery Techniques

Treatment Delivery

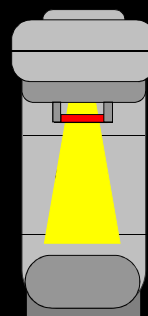
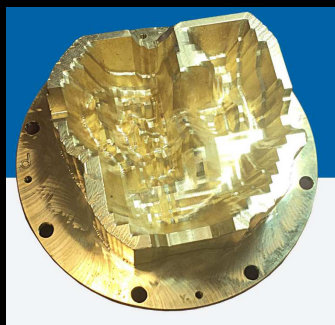
- Intensity modulated radiation therapy (IMRT) is a treatment technique where the uniformity of the treatment is dynamically adjusted to deliver complex dose distributions
- The goal of IMRT is to shape the radiation dose around normal tissues from multiple gantry angles
- There are multiple techniques for delivering IMRT, including Physical Compensators, Step-and-Shoot, Sliding Window, IMAT, VMAT, RapidArc, Serial Tomotherapy and Helical Tomotherapy



IMRT Delivery Techniques

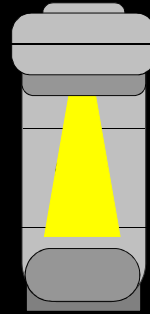
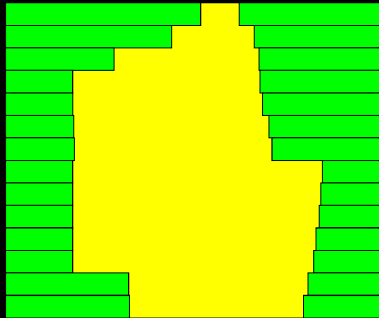
- Physical Compensators
- Multiple Static Segments (Step-and-Shoot)
- Dynamic Treatment (Sliding Window)
- Serial Tomotherapy
- Helical Tomotherapy
- Dynamic Conformal Arcing
- Volume Modulated Arc Treatment (VMAT)

Physical Compensators



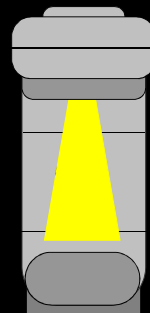
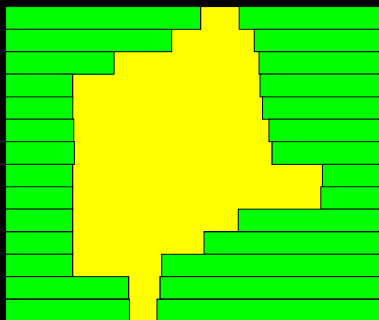
Physical compensators modulate the intensity by differential attenuation of the x-ray field

Step and Shoot IMRT



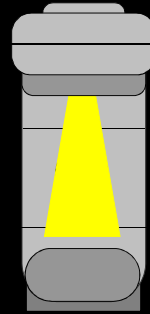
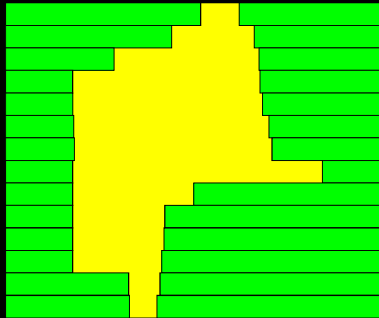
The MLC is in motion while the beam is off. The intensity by combining multiple static segments.

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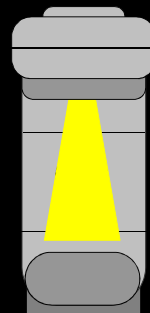
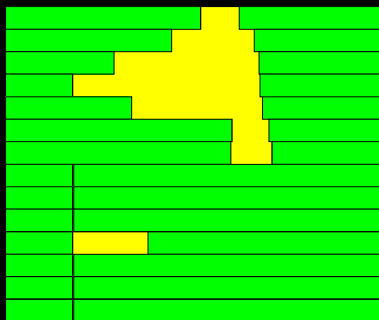
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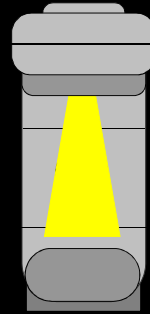
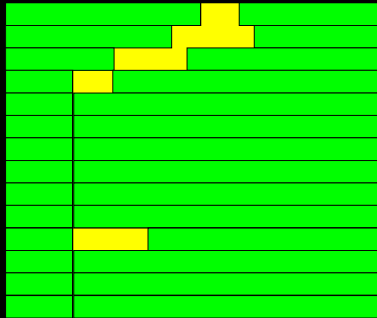
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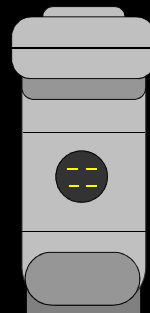
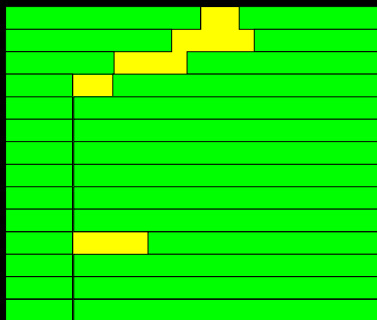
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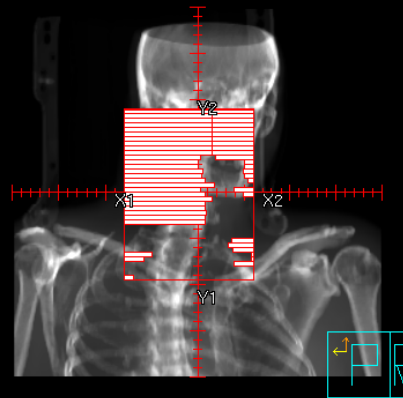
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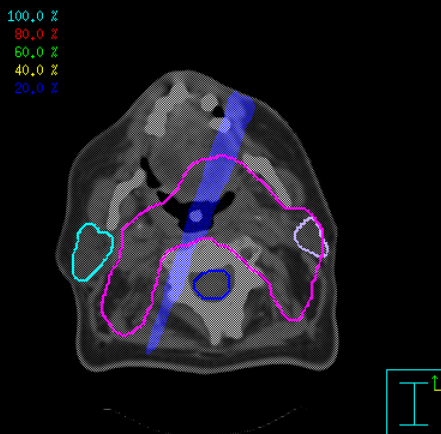
Step and Shoot IMRT

- Step-and-Shoot (also known as Multiple Static Segments) is a commonly used technique
- The radiation beam is turned on for each “segment” and off as the tungsten collimators “step” to the next shape
- Complex dose distributions are created by superimposing leaf shapes from 5 or more gantry angles



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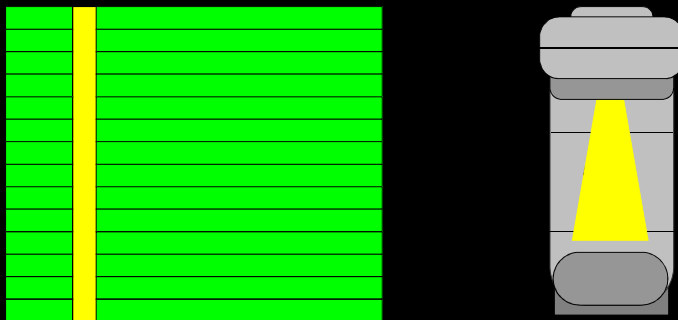


Sliding Window IMRT



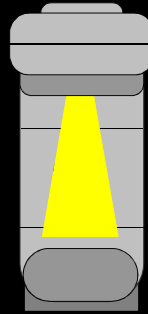
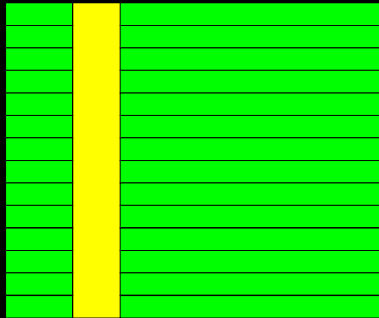
The MLC is in motion while the beam is on. The intensity is modulated by varying the gap width

Sliding Window IMRT



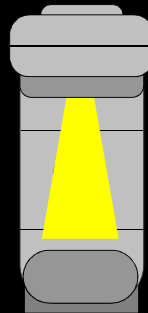
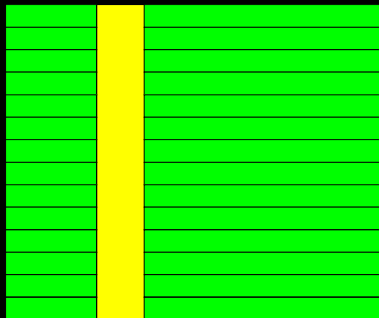
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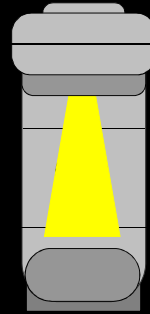
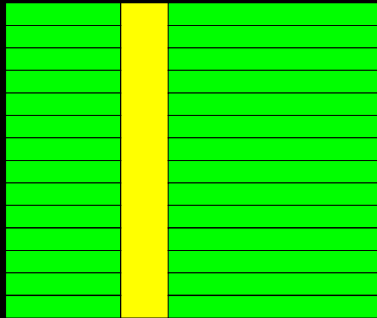
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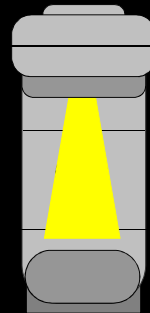
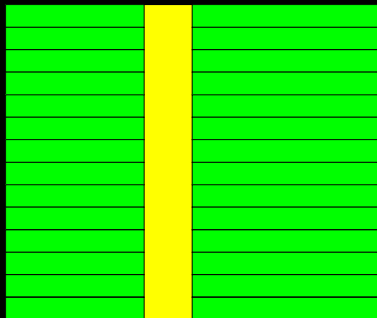
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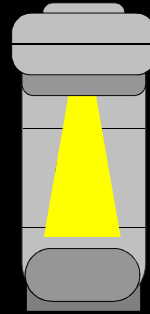
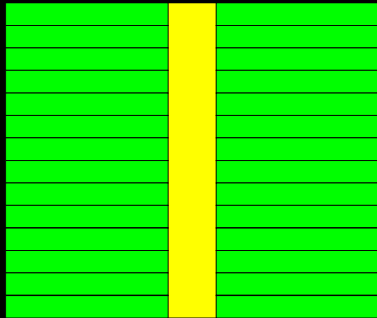
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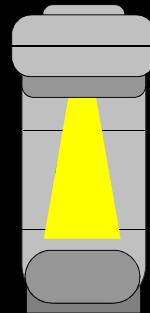
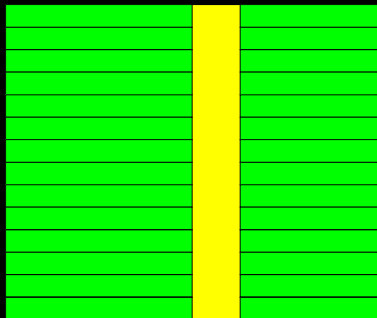
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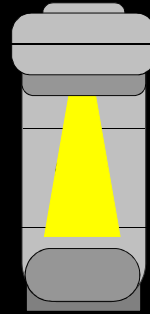
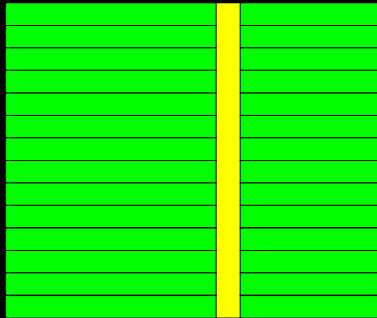
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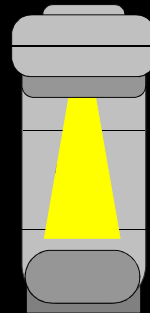
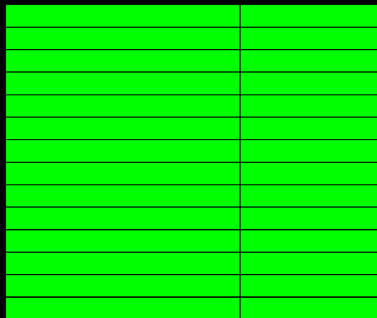
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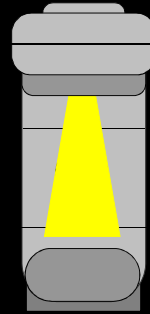
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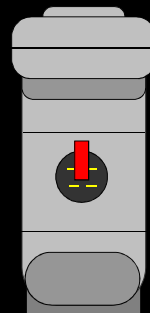
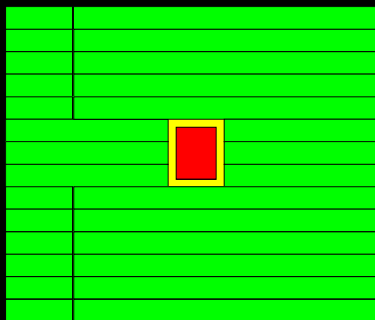
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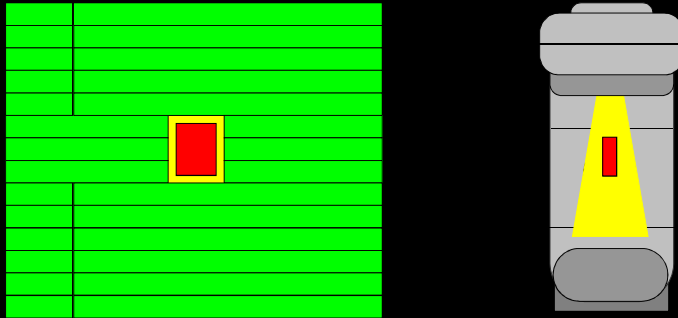
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Dynamic Conformal Arcing



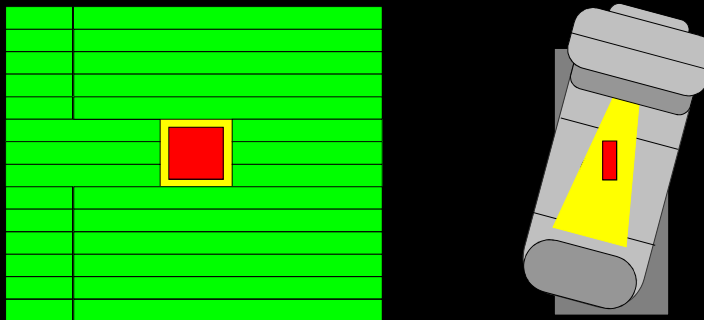
The MLC conforms dynamically to the shape of the target during gantry rotation

Dynamic Conformal Arcing



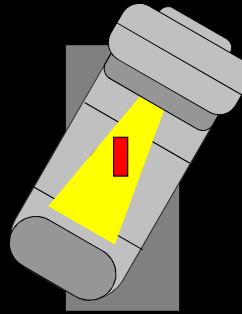
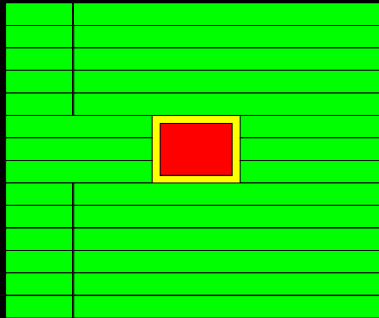
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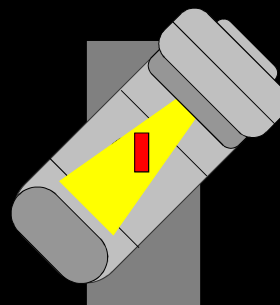
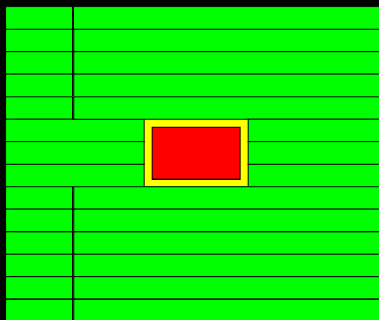
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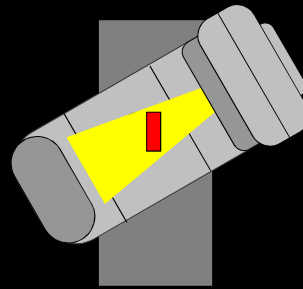
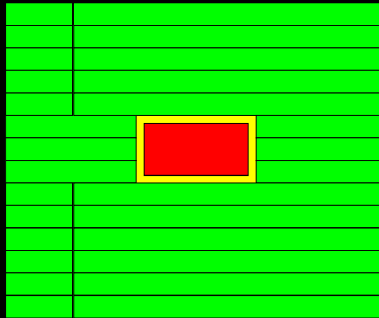
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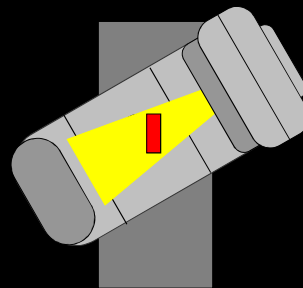
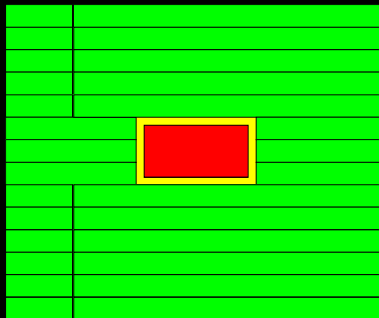
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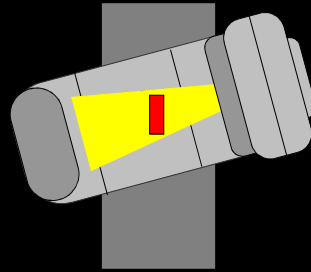
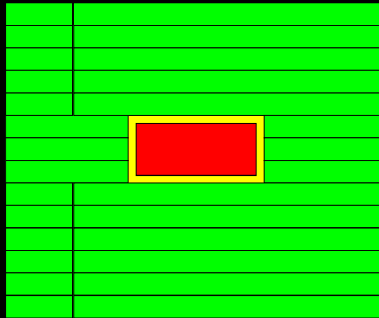
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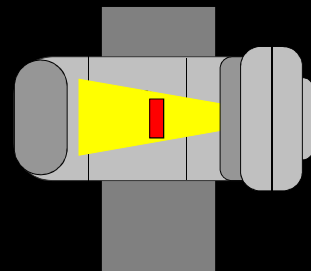
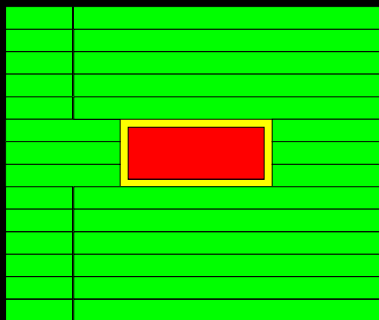
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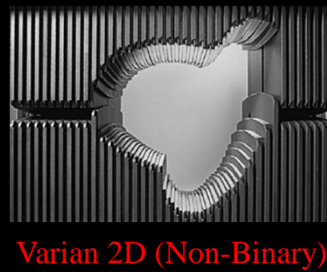
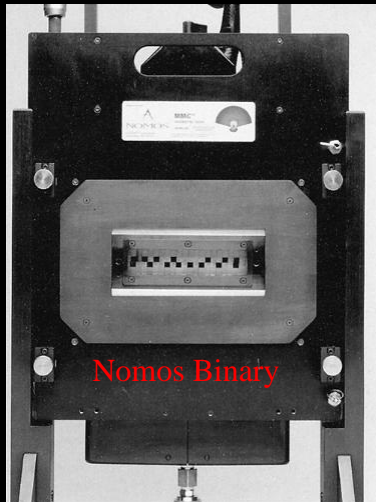
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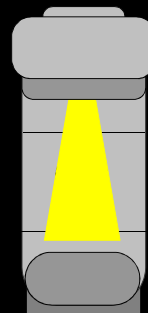
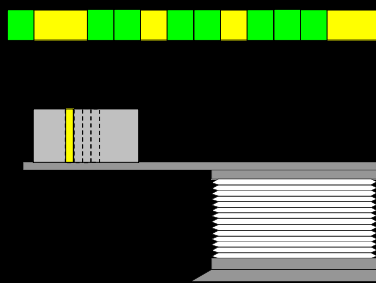


The MLC conforms dynamically to the shape of the target during gantry rotation

Binary Multileaf Collimator

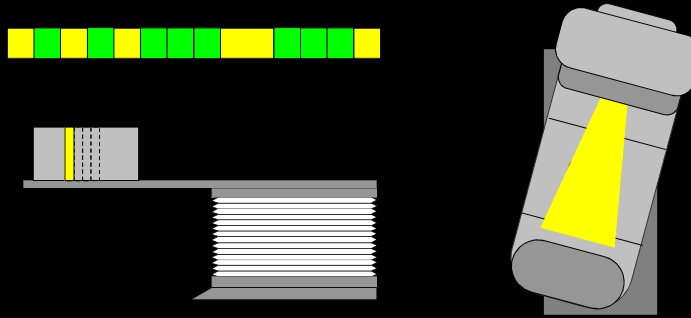


Serial Tomotherapy



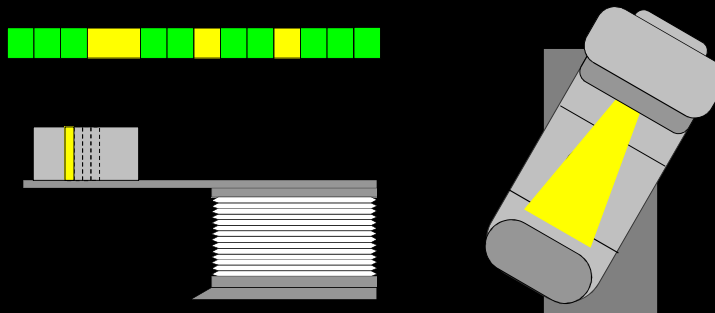
The Intensity is modulated using multiple rotating arcs where the intensity is modulated using MLC shaped fan-beams

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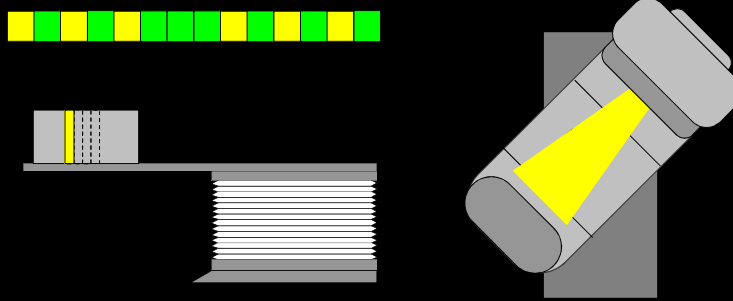
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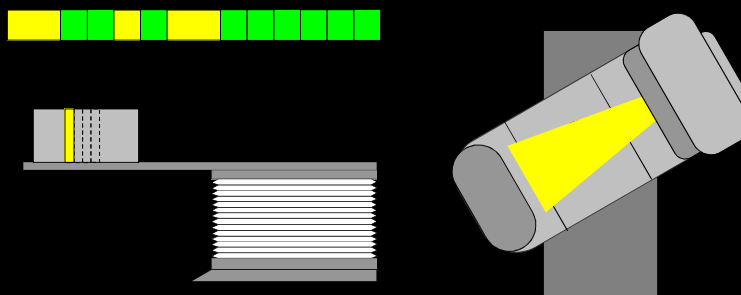
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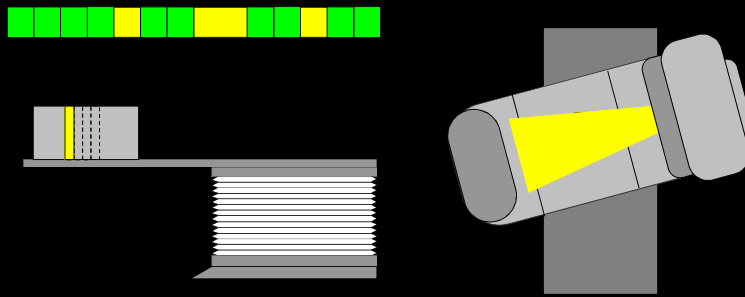
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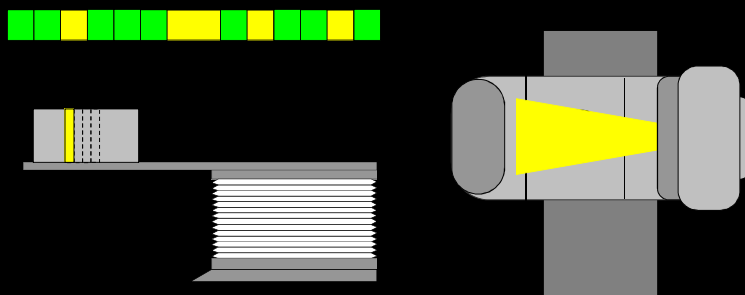
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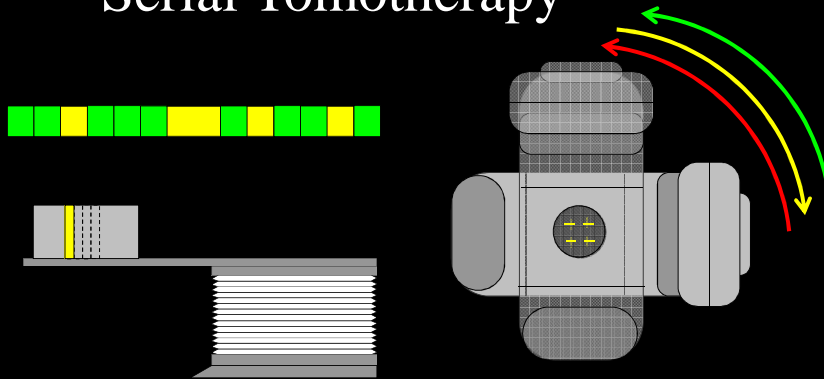
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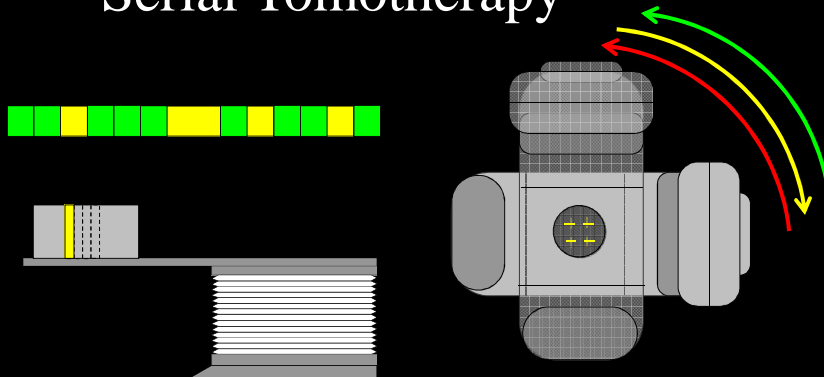
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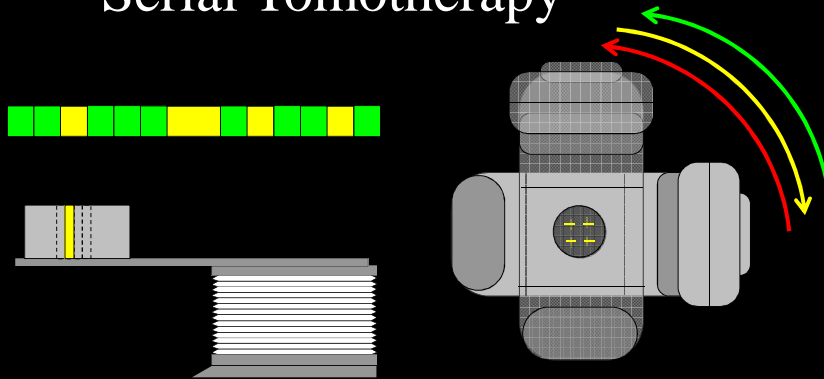
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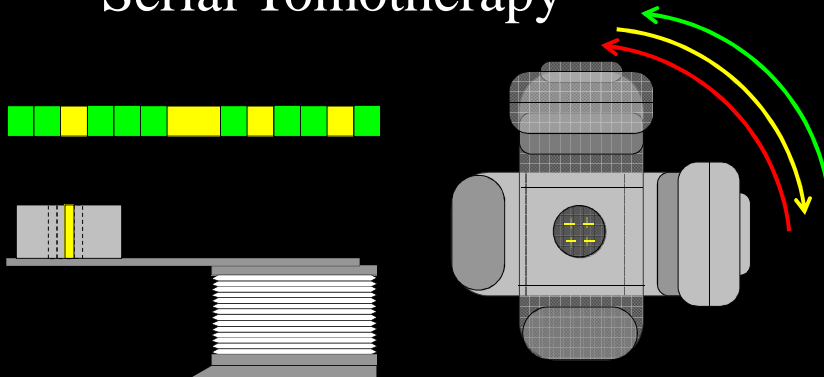
Dose is delivered to the entire volume by indexing the treatment couch and matching the individual fan beams

Serial Tomotherapy



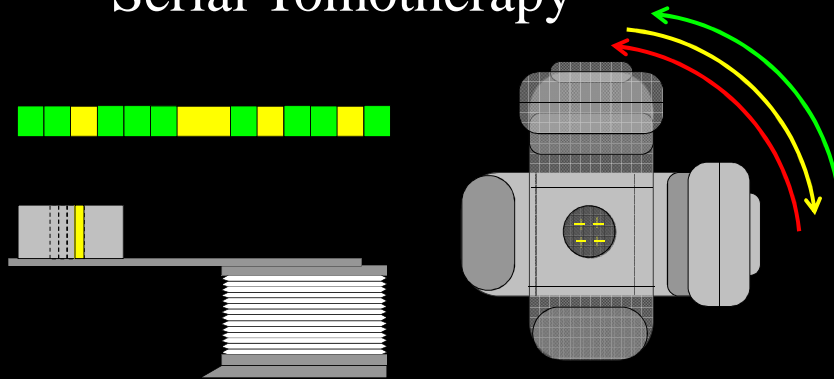
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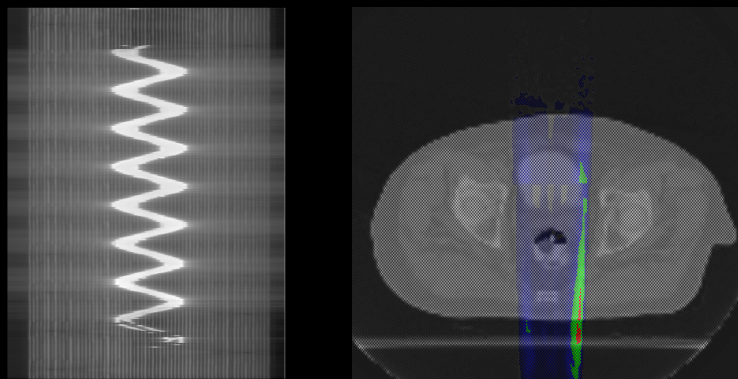
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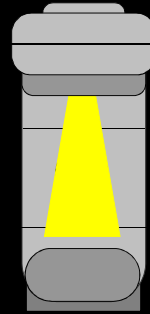
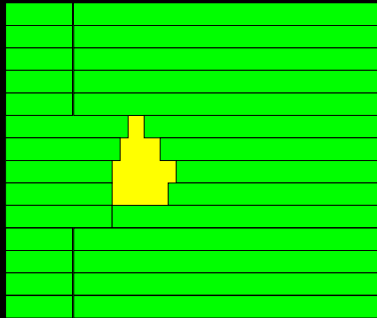
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Helical Tomotherapy



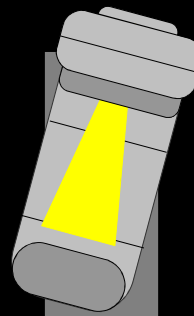
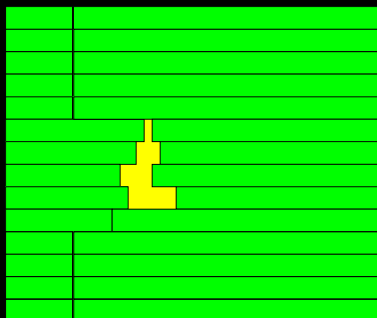
Dose is delivered during continuous helical rotation with a binary MLC

Volume Modulated Arcing



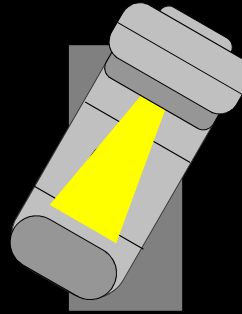
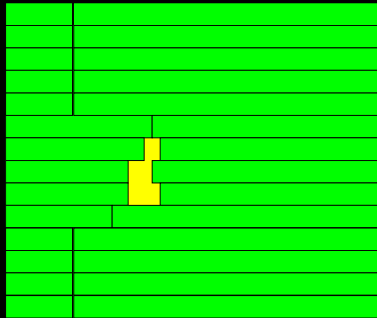
The MLC is used to dynamically modulate the intensity of the beam during gantry rotation similar to “Sliding Window” IMRT

Volume Modulated Arcing



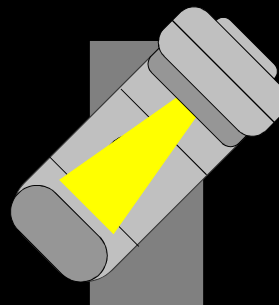
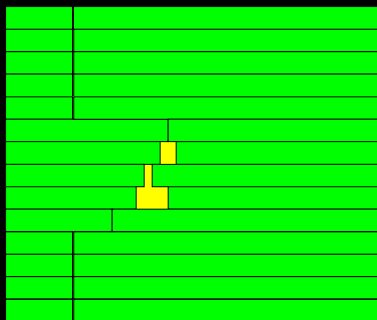
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Volume Modulated Arcing



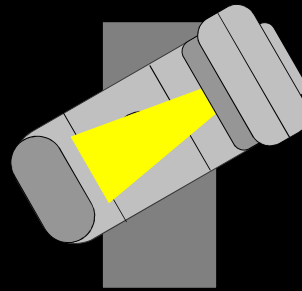
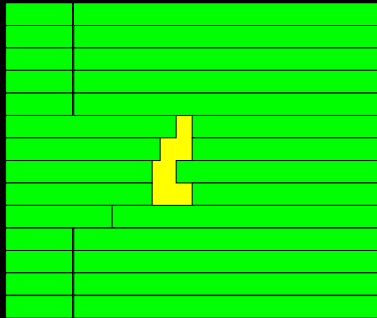
The MLC is used to dynamically modulate the intensity of the beam during gantry rotation similar to “Sliding Window” IMRT

Volume Modulated Arcing



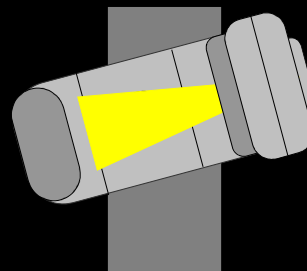
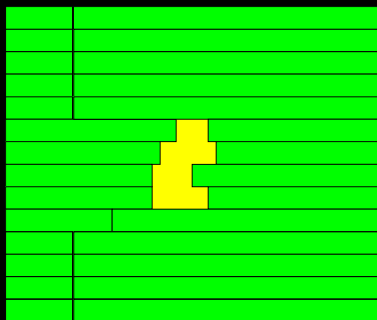
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Volume Modulated Arcing



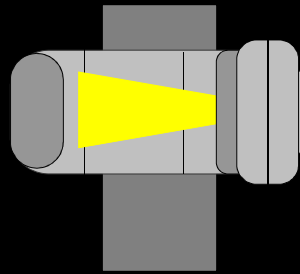
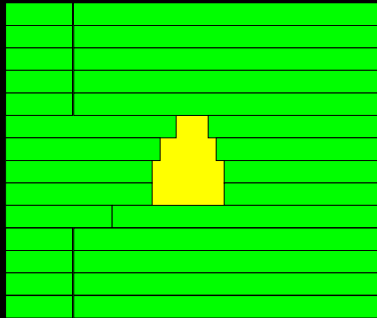
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Volume Modulated Arcing



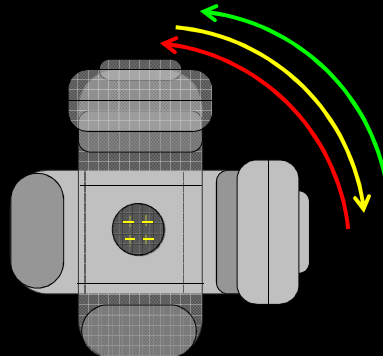
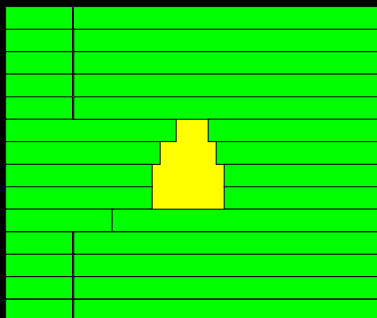
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Volume Modulated Arcing



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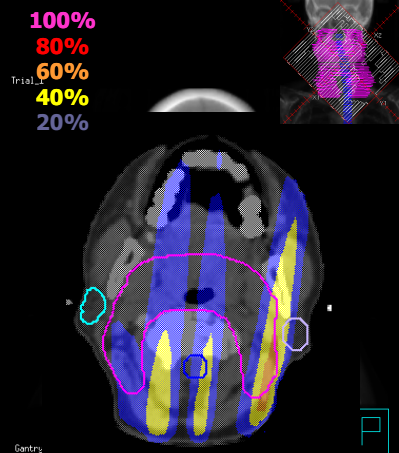
Volume Modulated Arcing



Volume Modulated Arc Treatments can be delivered with a single arc, or a series of arcs to build complex dose distributions

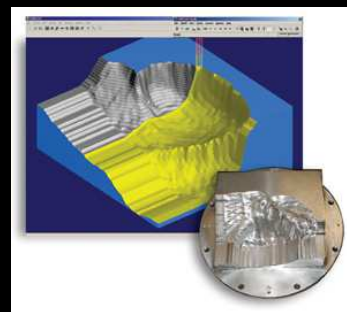
Volume Modulated Arcing

- VMAT is defined as modulated treatment delivery with continuous gantry motion
- During the gantry motion the field shape changes in order to modulate the treatment beam
- In addition, the gantry and/or dose rate of the radiation will speed up or slow down to assist in the shaping of the dose



Advantages of Compensator

- Milled compensators come the closest to delivering the theoretical intensity maps that inverse planning computers generate
- Compensator based IMRT can be implemented on older linear accelerators without MLCs



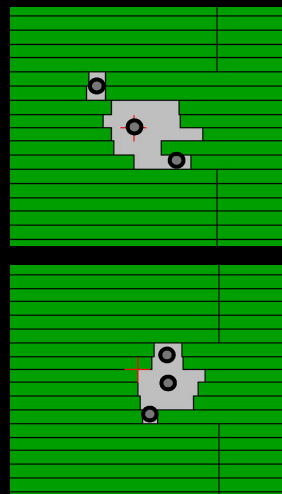
Disadvantages of Compensator

- Compensators are costly to manufacture and are single use (per patient)
- Treatment times are longer because of beam attenuation and the need to physically change the compensators between fields



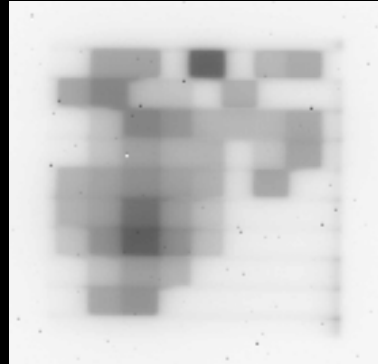
Advantages of Step-and-Shoot

- By its very nature, the Step-and-Shoot technique is dosimetrically the easiest form of IMRT to verify
- Siemens, Varian, and Elekta linear accelerators all support this delivery technique



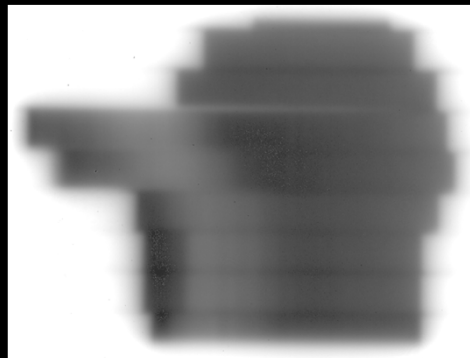
Disadvantages of Step-and-Shoot

- May require large number of segments to achieve an acceptable deliverable dose
- Incorrect leaf sequencing often results in a “checkerboard” effect with multiple 1x1 cm or small subsegments



Advantages of Sliding Window

- Sliding Window delivery can generate the smoothest dose distributions of the MLC based IMRT techniques
- Very quick to deliver each field



Disadvantages of Sliding Window

- The Sliding Window technique is more difficult to dosimetrically verify because of the steep dose gradients and its dynamic nature
- Leaf penumbra and gap width error can introduce significant dosimetric error

Advantages of Tomotherapy

- Because dose is directed at the target from multiple arc passes, greater normal tissue sparing can be achieved

Disadvantages of Tomotherapy

- Tomotherapy can have the longest treatment times of all four techniques depending on the number of arcs and couch positions
- Uses a dedicated system that is generally not used to treat non-IMRT patient

Advantages of VMAT

- Like tomotherapy, the dose is directed at the target over large gantry angles from multiple arc passes
- VMAT has the potential to deliver dose distributions that are more complex than the Sliding Window or Step-and-Shoot techniques
- Because the intensity is modulated across the entire width of the target volume, VMAT delivery is faster than other IMRT types

Disadvantages of IMAT

- Greater requirements for QA on the linear accelerator because of rapid leaf motion, gantry rotation, and changes in dose rate

IMRT Delivery Techniques

- Each IMRT delivery technique is capable of generating similar dose distributions, and thus similar clinical outcomes
- No one delivery technique has demonstrated a particular clinical advantage over another
- At present, preferences are based on other factors such as personal experience, throughput, equipment availability, etc...