Introduction to Materials Science and Engineering
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Lecture – 07
Symmetry II

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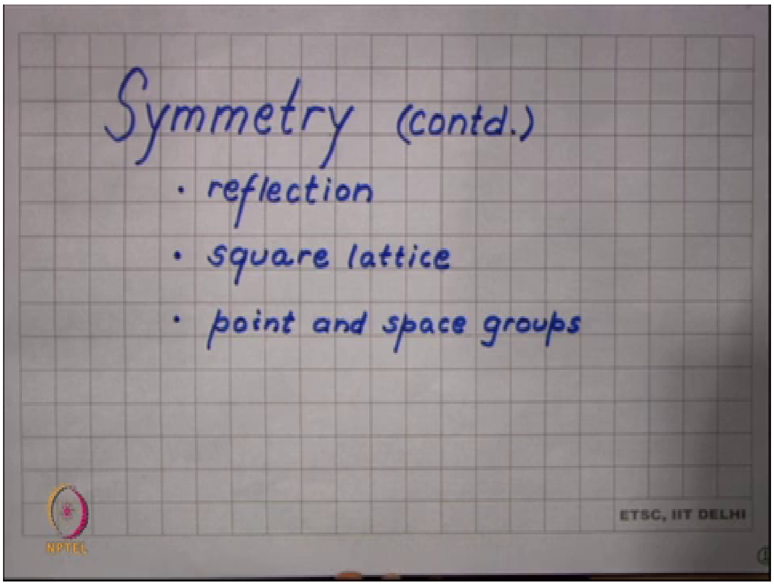

In the last lecture we started our discussion on symmetry. We discussed the translational symmetry which is the essential symmetry for any lattice, and we also discussed rotational symmetry. We continue our journey of discussing symmetry in this video with discussion of reflection which is one of the points symmetry. And then we will go on to discuss in detail the symmetries of a square lattice. And finally, we will define concepts; like point and space group which will be helpful in our classification of Bravais lattices

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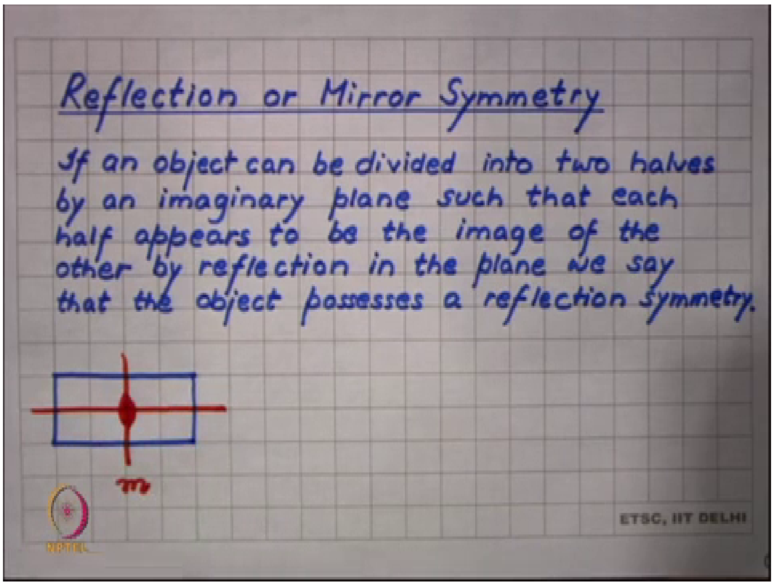

So, we next before discuss the reflection symmetry. Let us look at the definition here. If an object can be divided into two halves by an imaginary plane; such that each half appears to be the image of the other by reflection in the plane. We say that the object possesses a reflection symmetry. So, let us look at a simple example our rectangle, and if I divide this rectangle into two halves with this vertical plane, then we can see that the left half and the right half can be imagined to be mirror images in this red plane.

So, the red plane is a mirror symmetry of rectangle. So, it has a vertical mirror plane. It also has a horizontal mirror plane here, because the top half and the bottom half are mirror images of each other. In the symmetry definition, the mirror is always a two way mirror. So, the left is reflected into right and right is reflected into left. We also saw when we were discussing the rotational symmetry of this rectangle, that it has a twofold rotational axis at the centre.

So, we add that this is not an accident. This is a general rule of symmetry that whenever two orthogonal mirrors intersect the line of intersection is a twofold axis. So, all these rotational, all these symmetry are the point symmetry of a rectangle.

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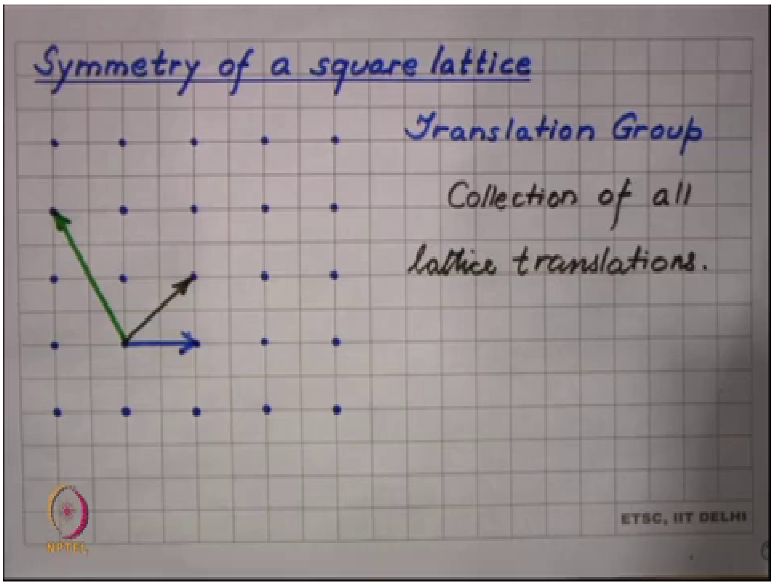

Let us now look at in detail the symmetry of a square lattice. We begin with the translational symmetry, we have already seen this. Let us add some translations recall that any vector from one lattice point to another constitutes a lattice translation, and if all points are shifted by this translation, the lattice will map into itself and will be a symmetry operation. So, this blue arrow is a symmetry operation or a symmetric translation of the lattice.

Similarly if I draw this diagonal black arrow, there is also a lattice translation. And if I draw yet another vector from this lattice point to that lattice point; that is also a lattice translation. So, a lattice has several translations, a collection of all these translational symmetry is called the translational group of the lattice. Translational group collection are group, all lattice translations.

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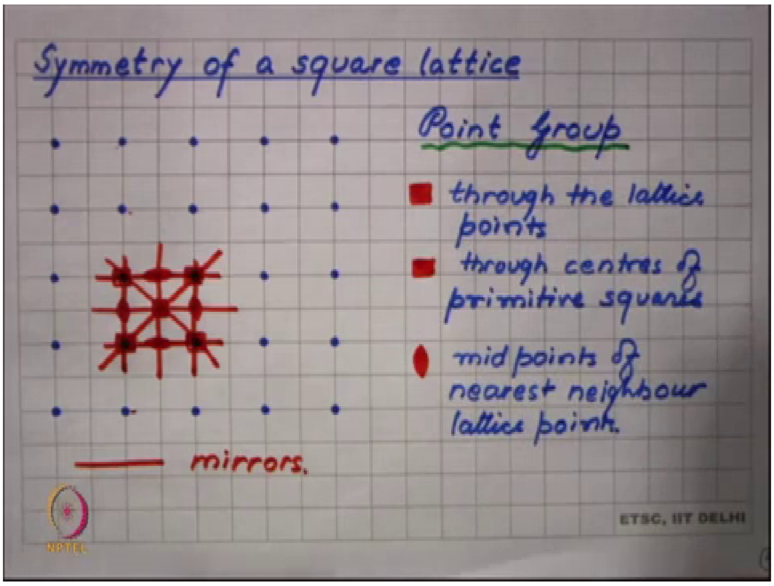

We also said that a lattice, the translational symmetry was essential, but it can have symmetry beyond translation; that is non translational symmetry. These are called point symmetry, because they leave some points unchanged

So, let us look at now the point symmetries of the square lattice. So, we can see that every lattice point, if you take an axis about that lattice point, then we can rotate the entire lattice by 90 degree to bring it into self coincidence. So, every lattice point, a fourfold axis passes through each lattice point. And since all lattice points are equivalent this passes through every lattice point.

So, I draw, I am drawing a little square which we had said is a symbol for a fourfold axis. So, we have a fourfold axis through the lattice point a four through the lattice points, we also find that there is a fourfold right in the center here, where there is no lattice point. The center of the square cell also a fourfold axis so, there is also of four through centers of primitive square we can call it.

Now, if we look carefully, we also find that, if we rotate the entire pattern by 180 degree about a point like this which is midway between two lattice points. So, a point which is midway between two lattice points, and I rotate by 180 degree then the lattice will also come into self coincidence. So, there is a twofold axis midway between two lattice points. So, here, here also add these locations. So, I have guides or two folds midpoints of nearest neighbour lattice points, and then you can see that if I take a line like this, it represents a mirror plane, because every point above will be reflected to equivalent point below, and every point below will be reflected into an equivalent point above.

So, there is a horizontal mirror. There is also this vertical mirror, and then there are, the diagonal mirror also. Of course, through these lattice points also we have mirrors; of course, by the translational symmetry of the lattice, all these symmetry operations will continue to be present at other locations of the lattice. Also we have shown it all inside one primitive unit cell.

So, a collection. So, we see that it has two four folds, it has two fold and it has mirror reflections. Collection of all these point symmetry operations is what is called the point group of the lattice. This will be called the point group of the lattice.

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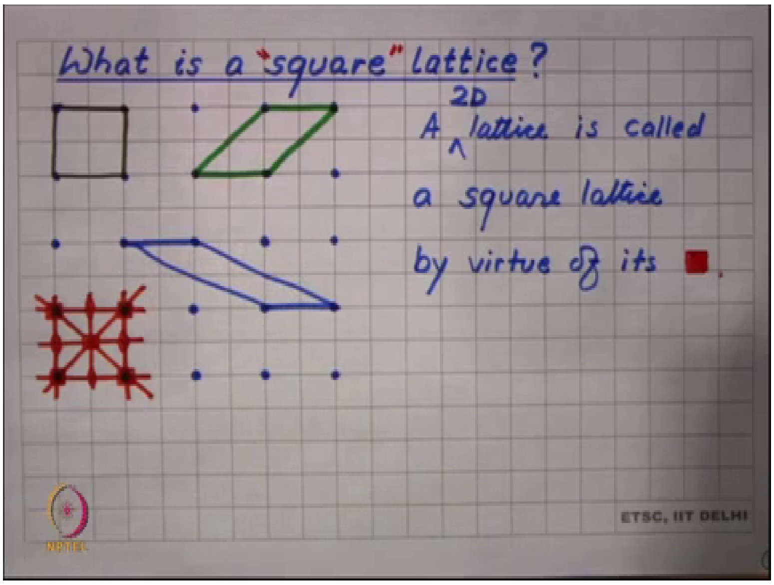

So, the question, now let us revisit our square lattice and ask the question that what is the basic definition, what is this squareness of the lattice? Of course, we can select, we can select a square unit cell, but then this is not the only unit cell which we can select. If we wish we can select this parallelogram unit cell also or we can select much more narrow parallelogram. So, all these different unit cells have different shapes, have different symmetries, but they generate the same lattice, they represent the same lattice and finally, the lattice has its own symmetry which is shown here, which we worked out in the.

So, it is the lattice symmetry which is what decides the nature or the squareness of the lattice. So, in this case we will say the presence of the fourfold is the definitional requirement of a square lattice; a lattice, 2 D lattice square, lattice by virtue of its fourfold axis, by virtue of its fourfold axis, not the unit cells shape, because unit cells shape can be of arbitrary shape as well.

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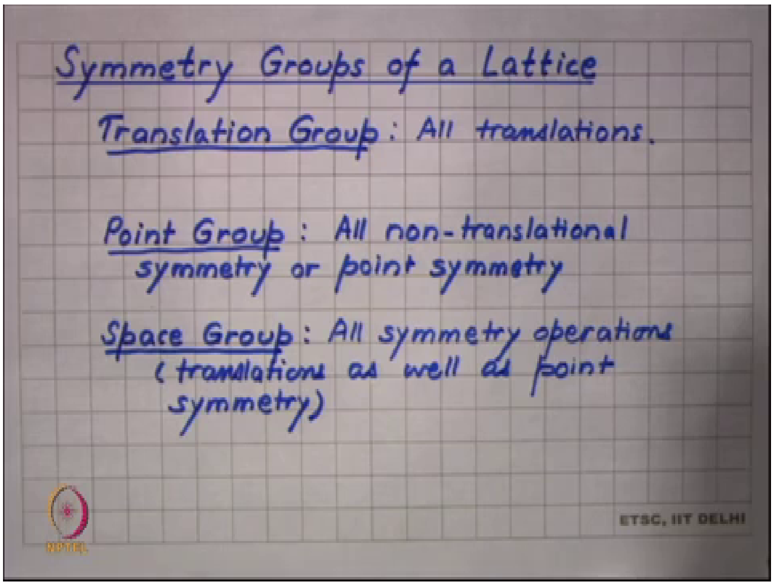

So, let us now summarize. We said that all translations form a group which is the translation group. If we look at all non translational symmetry or that is what is called point symmetry, because they leave some point unmoved or unchanged. All non translational symmetry or all point symmetry form a group which is called the point group and a space group, we are now defining space group, point group and translation group.

A space group is collection of all symmetry elements. So, all symmetry operations; that is translations as well as point symmetry is called the space group. So, with this definition, we will see that these are the definitions which are used for classification of lattices. So, we will take this up in the next video, where we will use the point group and space group symmetry as the classification basis for will lattices.