Laser: Fundamentals and Applications
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Lecture – 34
Application of Laser: Laser Spectroscopy

Hello and welcome, today's the fourth day of the 7th week of this lectures series. So, we have been discussing about the applications of lasers and we started with non-linear optics first and then we started looking at various different applications of laser in spectroscopy, and as a whole the application of laser spectroscopy. So, in the previous class we have looked into one of such applications which is known as leader. So, today we will be talking about several such other applications of lasers in different spectroscopy techniques.

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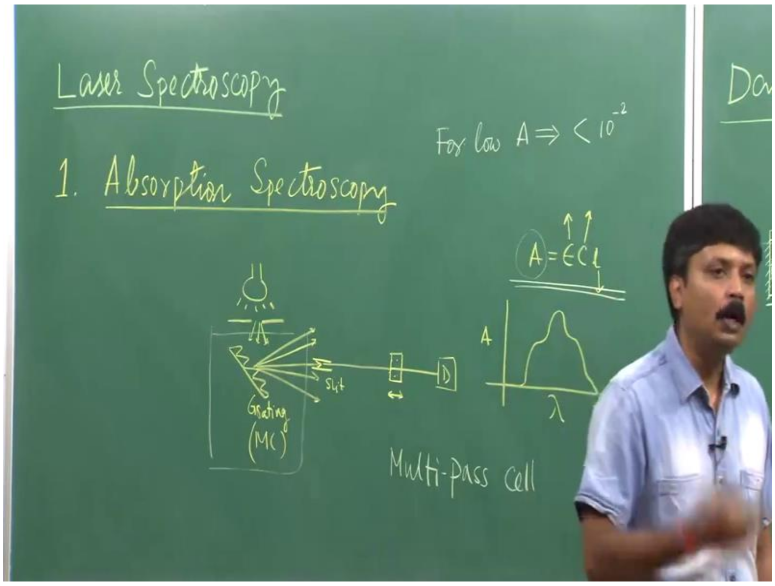

So, we will start with. So, what are the different areas in spectroscopy, where laser has been applied and essentially application of laser in those techniques have made the field really and reach.

So, we can start with a very very simple process like absorption. So, the first one that we will be talking about is absorption spectroscopy. So, what is done in absorption spectroscopy essentially is that, you have a suppose a molecule has you know one or more excited state then we provide light energy and we access all those excited states whichever is possible, and then we plot the absorption intensities as a function of wavelength. So, we get absorption spectra.

So, in conventional absorption spectroscopy what people use to do is to take normal light conventional light sources, and then they need to create you know monochromatic light or quasi monochromatic light. So, what they need to do is to you know disperse the light in terms is wavelength and then select and narrowband of wavelength and then allow it to interact with the sample and then measure the transmission from there they would get the absorption or absorbance in real term. So, essentially what you have conventional light source and then you take some amount of that. So, the light ray passes through this one and then you passed through a monochromator which is based on a grating.

So, this is grating. So, the whole thing is housed on a Monochromator and then they disperse the light according to their wavelength in various directions, and then you select a very narrow range of wavelength through a slit. So, this is a slit and whatever the width of that light wavelength that is allowed to interact with your sample. So, the sample is kept here and then after passing through this sample, you detect the intensity of light. So, if you know have a measurement of the transmission with or without the sample you get the measurement of absorption, and essentially you get a spectra as a function of wavelength and you plot absorbance and you get some spectra like that, where absorbance is epsilon is the polar extinction coefficient, C is the concentration of the sample or in other word redundant series and l is the path length of the sample of the light through the sample.

So, essentially this is the path length in this particular case. So, this is what people use to do when there was no laser. Now here what you have to do you have to really make sure that you have a very nice monochromator in some certain cases you have to have multi monochromator placed so that you can get narrow band light passing through. Now in that case the you know intensity of light can be really low. Now how did laser invention actually revolutionize this field of absorption; suppose you want to exit one particular transaction involving two states, then you know by quantum rules of quarter mechanics that your you know wavelength range of that light must be really very narrow.

So, that is why one needs to use a Monochromator, but in laser you have this already built in correct. So, a laser is a monochromatic you know most of the lasers can give you highly monochromatic light, much more monochromatic then you can think of. So, moreover the laser source is tunable. So, you really you know make this component that is the monovhromator absolute when you couple laser to an absorption spectrometer or you set up as an experiment using laser. So, in that case you can use the particular laser wavelength that you want exit selectively, and then you want to access another wavelength tune your laser whenever using a tunable laser for example, like a dye laser. And you can access huge range of wavelengths to in that way you know your absorption spectroscopy has become much more easier with laser ok.

So, for example, like simple diode lasers can be used remarkably well in case of absorption B spectroscopy. Second thing you know this conventional measurement this is fine till a certain amount of absorption value. If the absorption is very less what I mean is, if the absorption cross section of that particular material under consideration is very very low then the absorbance value also will be very low. So, for low a value this technique with conventional absorption spectrometer maybe really really you know it may not be so good, and say if it goes said the absorbance value if it say is less than 10 power minus 2 to 10 minus 3, then it is very very difficult to use this conventional absorption spectrometer.

So, in that case one can come with laser which has all the same properties like you know you have mono chromaticity, and apart from that there is a high degree of collimation. So, in that case one can use laser in a different way to you know get access to the overall absorption intensity or absorbance. How? Because if you look into this relation it depends on the concentration it depends on the length of the light passing through the sample and epsilon is a constant for a particular molecule at a particular wavelength. So, you cannot do anything to the epsilon value. So, you can play with the concentration and length when your concentration you know the variation in concentration is not in your hand for example, like if you say have very tiny amount of gas present in a mixture or a you know a pollutant in a very very low amount in that case you cannot you know increase the concentration of that, but still you have one parameter that is the path length in your hand.

Now, in conventional way if you want to increase the path length you have to just keep on increasing the length, and you have to probably you know in order to get a proper absorption spectra for certain molecule, certain species, you may require like 100 meters and you know this can be really you know in practical to make it, but you can access such a long path length using something called multi pass cell. So, what is multi path cell or multi path cells is, you have almost like a cavity where you ok.

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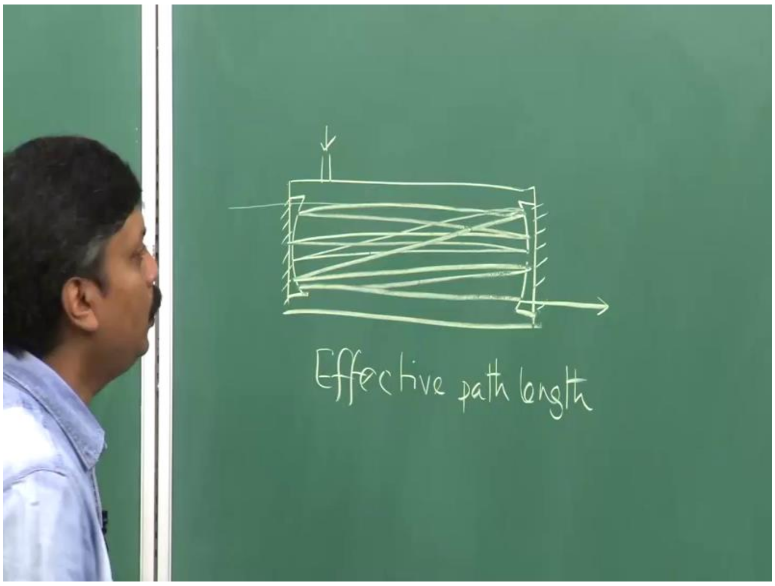

And this is nothing, but (Refer Time: 10:30) and your sample comes in through this one and filled it. So, you evacuate whatever material is inside and then insert your sample and then you send in a light ok.

So, what will happen, it will go through and keep on travelling between this mirrors and at is point they will go out fine. So, in this way they are actually bouncing of the mirror several times, and the effective path length is essentially twice the number of such roundtrip multiplied by the distance between this two mirrors. So, you can imagine suppose it you know reflex back and forth by say 100 times, and if this multi path cell is say one meter. So, what will happen? So, it will be travelling 200 meters of you know distance. So, there by you can increase the l, you can increase by enormous amount you can increase by 10 power 4 times if you can really aligned you light.

Now, what is the advantage of using laser in this case is that laser has very low divergence. So, while traveling back and forth they will not diverge you know remarkably. So, they will be pretty much collimated and therefore, you can access this multi pass cell properly, and you can achieve the absorption or you can measure the absorption spectra of a very weekly absorbing molecule, which has very very low absorption cross section or for example, if you have really low concentration of some material which you cannot measure using a conventional absorption microscope. So, you can see application of laser can really do wonder in even some established spectroscopy techniques.

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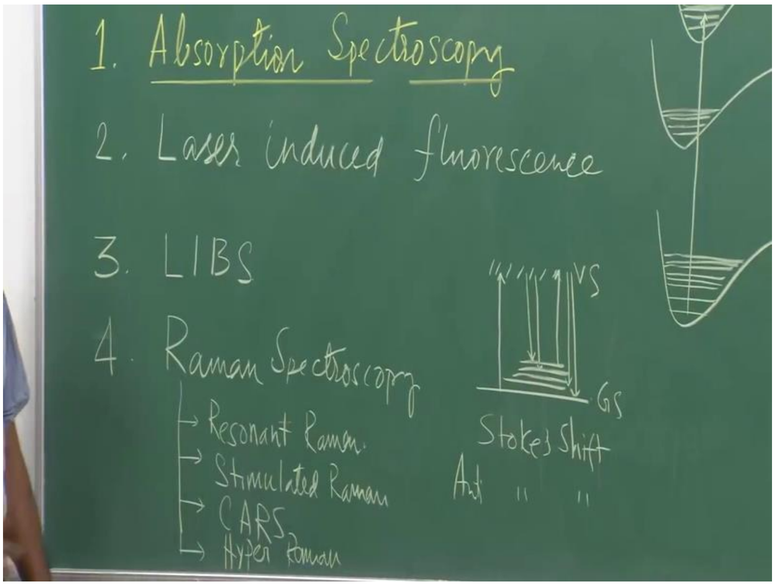

Very similar to this is another technique which is called cross and spectroscopy and very use this laser; you have essentially laser induced fluorescence ok.

So, by selecting a particular narrowband laser light, one can excite a molecule to a particular state of interest. So, just I will give you know and a simple example. So, suppose this is this is the ground state. So, by using a laser without populating this one you can populate this state. So, this is a very very simplistic view, there are so many things involved here I am not going to the detail, but I wanted to tell you that using laser you can to selective excitation and you can follow its fluorescence.

So, this laser induced fluorescence have you know its application in various different things, if you want to prove the dynamics of any particular exited molecule, you can use LIF. If you want to measure whatever the product or branching ratios followed by a photo excitation in a molecule you can use LIF you can use LIF or various diagnostic purposes in you know material science as well as in medicines ok.

So, there are several such applications are possible. Now there are several other things one of them we will be talking about a little bit in detail in one of the following classes, is say laser induced breakdown spectroscopy; by using laser utilizing its enormous power and narrowband energy that is you know monochromaticity one can actually utilize this particular mode of spectroscopy that is laser induced breakdown spectroscopy to find out the composition of any material even this can be applied in C2. So, where laser is used in manufacturing in you know treating a surface or in characterizing a surface or say using a for cladding or you know any other type of you know like penning, they combination of LIBS with those techniques can actually give you and in situ information about the compositions of some material.

So, this is one of the applications that this laser has in terms of laser spectroscopy. The another one is probably one of the most important thing is Raman spectroscopy which is based on the principle of Raman scattering; which says that if you have a molecular ground state and if you come with a sufficient amount of electric field which is coming from your light, then you can force the molecule to take that photon and go to somewhere we represent this somewhere as a virtual state, and then it immediately scatters back. So, while discussing about non-linear optics we talked about a polarization and we essentially went to the non-linear polarization. Before the non-linear polarization takes place the linear polarization that is created has this you know process going you know on there.

So, this scattering is known as Raman scattering, it can you know give you stoke shift as I shown here and suppose if the expectation is from somewhere here instead of this place, if suppose exit excitation is from here and it comes back over here. So, of course, the scattered intensity we will have more energy than the input energy. So, that will be called anti stokes. So, you have stokes shift as well as anti stokes shift in Raman spectroscopy. The Raman spectrum that you get from a particular molecule can be used as a fingerprint of that particular molecule. So, like other they while discussing about leader we you know brought in this you know one of the probe techniques has Raman spectroscopy.

So, this using this principle of Raman spectroscopy one can generate the Raman spectra and one can you know detect particular molecule present there, and this is you know as a said this is fingerprint thing. So, using this particular technique is really really important;

suppose you have a bunch of molecule present in an ensemble and if you get a Raman spectra of the species that you actually are looking for, then that will give you on unequivocal proof that particular molecule is present there. Now you can understand in order to make the molecule polarized you need a really the high intensed light, you also want to have a very narrow band light to do this one because this energy shift may not be that much they are not generally too much. So, you have broadband light will not work here.

So, you really need a very narrowband light and then you look at the energy difference between the photon that is coming out and the photon that you are using two cause the excitation. Now this is just about Raman spectroscopy, but there are several you know different modes of Raman spectroscopy that are possible and that have been you know possible because the laser is there to do the job, otherwise it would now been possible to do. So, for example, I will take some names we will not go through them in detail within Raman spectroscopy, you can think of resonant Raman spectroscopy, you can have stimulated Raman which is another also another source of you know wavelength conversion.

So, stimulated Raman you can have coherent anti stokes Raman scattering or in short curves, which say I have been which is rather comparatively newer techniques and it has gain a tremendous momentum in last few years, and this has been applied to understand various processes in living system fine. You can also have a type of non-linear spectroscopy in the domain of Raman scattering, which is known as hyper Raman. So, this is a non-linear process. So, all this you know oxides of Raman spectroscopy techniques are you know they exist because of the laser otherwise, it would not be possible. So, we do not really have much time to go through detail of these things. So, whoever is interested about this one, you can pick up any standard book on spectroscopy and get an idea about various different Raman spectroscopy techniques, and how lasers are used which lasers are used what are the modes of experiment, what are the information that they can you know be obtained using those techniques in greater detail you can find those.

So, with this idea we will move on to other kind of applications directly. So, we will mostly take the advantage of the laser assisted absorption spectroscopy or at least using the absorption process to get an idea about a very important application for various industries ok.

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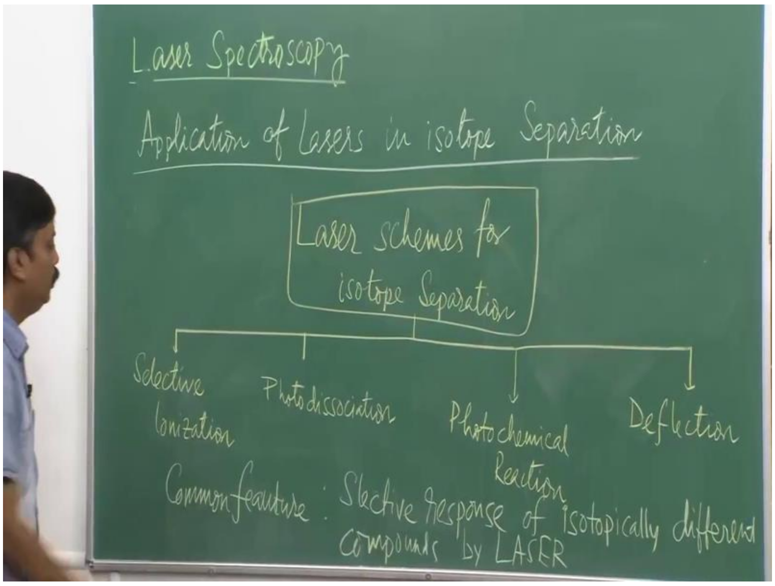

So, what we are going to look at now application of lasers in isotope separation. Now in chemistry the separation technique is very much known subject and say we will taught subject in your you know undergraduate or postgraduate level. If someone is given a mixture of compounds using conventional chemical techniques one can separate them.

When it comes to isotopes say for example, I give you two isotopes, one is nitrogen 14, another I give you nitrogen 15. Differentiating them chemically and isolating or separating them chemically is hardly possible. Reason there chemical properties are pretty identical then chemical separation techniques they utilized the difference in chemical behavior or chemical responses of two different materials, but here since they are identical in their chemical behavior it is hardly possible to separate them using there know you know routes.

There actually you can bring in laser source and optically separate them or at least you can you know bring two isotopes at a you know in a condition that you can use a chemical means a conventional chemical means after world to separate them. So, how that is you know done we will look into that. So, there are schemes for isotope separation there are several scheme, but broadly we can you know categorize this schemes into four different classes. So, the first one is selective ionization, the second one is selective dissociation, I will say photo dissociation. The third one is by allowing or photochemical reaction and the fourth one is selective photo deflection I will write the only deflection.

So, we will talk about this you know these different schemes in a bit detail, but before that we will if you look at this classification of the schemes, one thing is common in them. So, what is the common feature? Common feature of all these different scheme is that selective response of isotopically different compounds by laser radiation. So, all this process ionization phonon dissociation deflection or a chemical reaction they just utilize this selective response from set of isotopes when you use a selective wavelength from laser. So, what are the two primary things that are important here? So, or the important factors that you need to know about the laser induced isotope separation ok.

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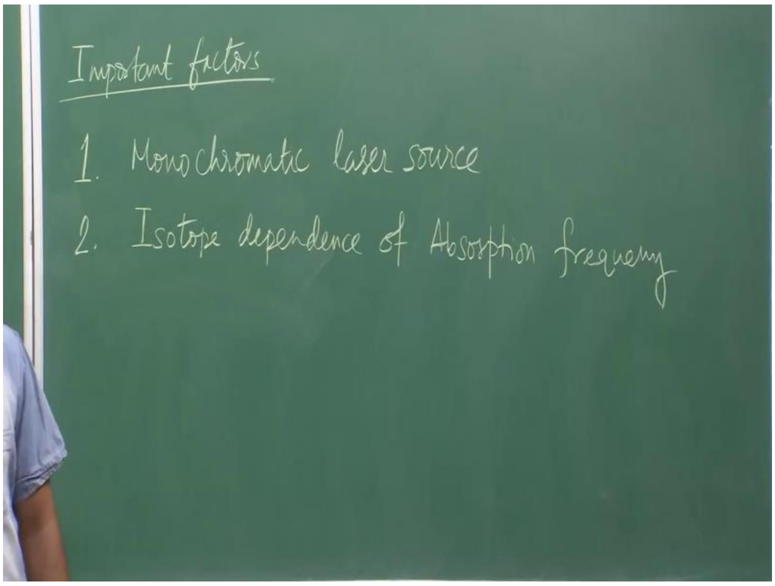

So, one thing is you must have monochromatic laser source and second thing is isotope dependence of absorption frequency, I am talking about light absorption frequency.

So, what I am saying here is that this laser induced separation methods they utilizes the monochromatic property of laser light, and second thing it you know utilizes is that the light absorption frequency or wavelength of two different isotopes or three different isotopes are shifted from each other. Shifted such that very narrow line with laser can see them in a distinct way; utilizing these two properties one can go ahead and do the isotope separation and this is you know very good example of a high resolution spectroscopic means to have a huge application in fundamental science as well as in industry. We will look into all these things in the following class.

Thank you very much.